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13. ABSTRACT ( <i>Maximum 200 Words</i> ) Is it feasible to develop a battalion level stochastic simulation of combined arms operations? A methodology for application of such a model in support of type studies in the area of tactics, doctrine, organization, and materiel was developed. A set of characteristics of the model to enable this application was then developed. Chapter II describes the combined arms battalion level system and establishes measures of effectiveness to both evaluate any model considered and for future use in applying the model. Known models are described and evaluated. No model currently exists which successfully satisfies the requirement for a combined arms battalion level simulation. Detailed analysis of the ASARS Battle Model is used to describe essential characteristics for such a model. A conceptual framework for model completion is outlined.			
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A COMBINED ARMS COMBAT MODEL  
CONCEPT FOR DEVELOPMENT

A thesis presented to the Faculty of the U.S. Army  
Command and General Staff College in partial  
Fulfillment of the requirements of the  
Degree

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The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

## ABSTRACT

The problem undertaken in this thesis is the determination as to whether or not it is feasible to develop a battalion level stochastic simulation of combined arms operations.

Initially a methodology for application of such a model in support of type studies in the area of tactics, doctrine, organization and material was developed. From this point of potential application, a set of characteristics of the model to enable this application was developed. Chapter II describes the combined arms battalion level system and establishes measures of effectiveness to both evaluate any model considered or developed and for future use in applying the model in support of a specific study objective.

All models known to exist which have potential for application in studies of the nature described are reviewed in detail in Chapter III. The strengths and weaknesses of each model considered are listed for future use. The results of this review is the conclusion that no model currently exists which satisfies the requirement for a combined arms battalion level simulation. Several programs do exist however, which successfully model portions of the system.

Concluding that no single model satisfying the requirement exists and having a detailed description of the battalion level system in terms of the functions of land combat, an executive routine that should be used in a combined arms model is then developed. Detailed analysis of the ASARS Battle Model is used as a vehicle to describe the essential characteristics of this executive routine, and a method of control (Event Sequence - Time Constrained) and level of resolution is described. The executive routine is developed through programming and demonstration of operability, to present the type and level of detail required for documentation of such a model.

Using the executive routine developed, and in consideration of the strengths and weaknesses of the relevant models reviewed earlier, a conceptual framework for model completion is outlined. Those areas requiring further significant research and development are identified as Target Acquisition and Surveillance, Casualty Assessment, Command and Control and Dynamic Maneuver. In each of these cases, either the methodology for satisfaction of these needs is presented or reference to sources of acceptable existing logic is made.

It is concluded that the development of a combined arms stochastic simulation of battalion level is within the state of the art. The bulk of the work

required to develop such a model has already been completed and it remains to integrate these specialized efforts. Considerations with respect to management of such a study effort are noted and recommendations for implementation are offered.

It is recommended that:

1. a 5 year three phase development effort be undertaken.

2. a project manager with an office of 10-15 personnel be dedicated to the project for its duration.

3. the priority for use of a CDC 6600 type computer be assigned to the project. (The CDC computer is specified only because of the number currently in use in Army R&D. A larger capacity faster operating computer such as a third generation IBM would be preferred although a CDC 7600 may be sufficient.)

4. contract funds of approximately \$500,000 be allocated to the program for civilian contracting in addition to priority for use of Army resources in accomplishment of the project.

5. specific objective should be assigned to the project to guide yet not restrict the development effort.

#### ACKNOWLEDGMENTS

I indeed would be remiss if I did not at this time express my appreciation to all the many persons who made this study possible. Although I anxiously assume full responsibility for the contents and conclusions of this study I could not be so presumptuous as to suggest that it all constitutes original thought.

I owe a special debt of gratitude to Mr. Robert J. O'Neil (U.S. Army Retired) of Fort Benning, Georgia for his years of guidance and painstaking review of several preliminary drafts, and of course to my wife and children whose constant support, to include typing, made this entire undertaking possible.

JOSEPH F. PAONE

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## Chapter I

### INTRODUCTION

The science of Operations Research/Systems Analysis has come of age and proven itself adaptable to a variety of problems. A major application of this scientific approach in the Department of Defense has led to the development of a large number of computer simulations of combat. There currently exist a large number of simulations dealing with various levels of organizations ranging from large (Division and above) to small (Platoon and below) combat units. The need for a battalion level combined arms stochastic simulation, to assist the decision-maker in selecting new weapon systems for development or the evaluation of organization and training options for implementation, has been well documented. It should be emphasized that although battalion level simulations exist, none successfully model the full combined force. Such a model has not yet been developed. The feasibility of developing such a simulation will be investigated by testing the following hypothesis.

### HYPOTHESIS

The development of integrating logic in the

form of an executive routine will permit the application, after appropriate modification, of a series of existing programs to create a stochastic simulation model of the Combined Arms Battalion System.

#### BACKGROUND

The term "battalion" specifies a level of organization of two or more company sized maneuver units while combined arms describes the integration of various tactical units of principle interest in this study. Battalion is defined as a "unit composed of a headquarters and two or more companies or batteries"<sup>1</sup> while combined arms is defined as "more than one tactical branch of the Army used together in operations."<sup>2</sup> For purposes of this study effort the element of interest is that organization which can control and support from two to five major subordinate maneuver elements (company sized). The subordinate maneuver unit can be either Infantry or Armor. The element of interest will also be capable of providing support (both combat and combat service) from organic systems or controlling the application of this support from external forces. This support will include but not be limited to Artillery, Tactical Air Force, and Army

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<sup>1</sup>Department of the Army. AR 310-25, Dictionary of United States Army Terms. (June 1972), p. 82.

<sup>2</sup>Ibid, p. 126

Helicopter support.

Since World War II the field of force development and materiel development in the Army have made increasing use of advanced techniques of operations research and systems analysis. With the advent of the high speed digital computer the capacity to measure and rapidly record factors describing the combat actions of units has provided an opportunity for detailed analysis of combat operations. A large number of computer simulation models have been built and exercised in the area of combat analysis. These models deal with units ranging from the individual level and small independent unit up to and including Theater Army level operations. The absence of a model capable of treating combined arms operations at the battalion level has been a serious shortcoming of this hierarchy of models.<sup>3</sup> Considerable resources have been expended at modeling various aspects of the combined arms model but to date the logic necessary to integrate these functions has not successfully been presented.

A significant factor contributing to the problem of modeling combined arms operations is the complex interaction and variability of the functional areas of combat.

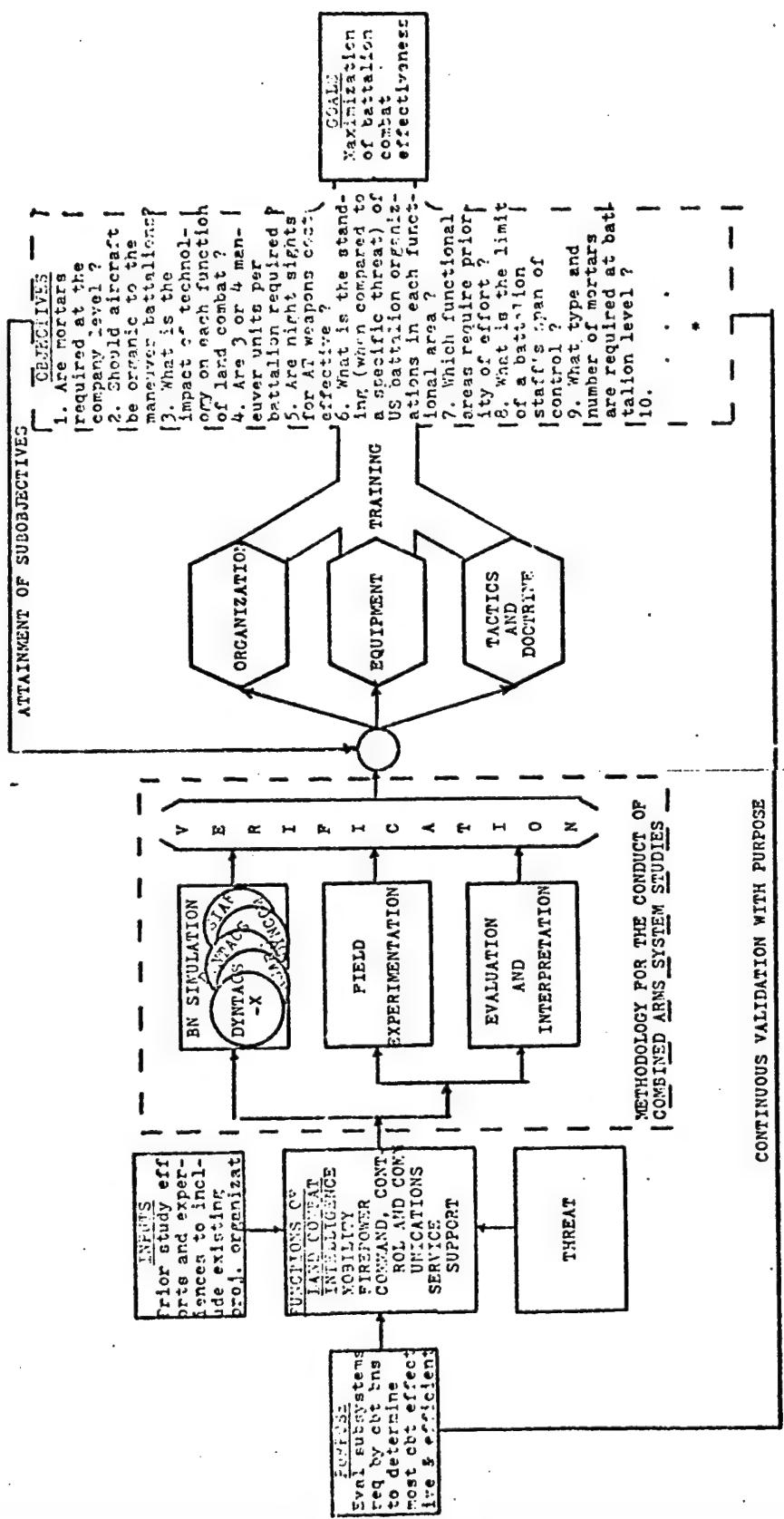
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<sup>3</sup>Combined Arms in this application describes the tactical employment of two or more arms of the Army, eg. Tank/Infantry teams and Task/Forces.

Explicit modeling of all factors interacting in the complex environment of combat must be accomplished to permit the required depth of analysis of the combat action. This need for explicit modeling of the interaction of variable factors in this complex environment dictates the development of a stochastic simulation to approximate the randomness as opposed to the fixed rule or relation applicable to the combat process.

#### PURPOSE

This paper undertakes the development of the detailed methodology and investigates the feasibility of building a combined arms stochastic simulation model of combat at the battalion task force level. This model could serve as a critical analytic tool for development and evaluation of organization, equipment, tactics and doctrine as well as training requirements of the Army of the near, mid and long range time periods. Figure 1 places the battalion simulation into a conceptual framework for application. Force Development has precipitated the development of large scale war games and simulations, normally at division and higher levels, to assist in arriving at credible organization options. To date the utility of higher level gaming/simulation efforts has been limited due to an inability to resolve two sided conflict at brigade and battalion levels in a valid manner. This is particularly true when the forces under consideration



- The listing is a sample of type objectives

**Figure 1**  
Combined Arms System Study

logically require meaningful integration of Infantry and Armor units with normal support, to include aerial systems. Figure 1 describes a type study that could be undertaken to answer one or more of the questions listed under Objectives. The goal of any such study could reasonably be described as maximization of battalion combat effectiveness.<sup>4</sup> The present state of the art in the field of combat developments provides a means of accomplishing each task described in the referenced system with the exception of the battalion level simulation. The circles within this block in the figure contain acronyms for models which have been completed (or are nearing completion such as the Army Small Arms Requirements Study (ASARS) battle simulation) and represent unique contributions to the endeavor of developing a truly integrated combined arms model. The purpose of this study is to evaluate each contribution and describe a method for their integration. In this manner the feasibility of developing such a combined arms model will be fully investigated.

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<sup>4</sup>The term maximization is carefully selected for use in this context. Its use recognizes existence of constraints. These constraints could take the form of funding limits, force levels or policy. The study tools must be capable of treating all reasonable constraints as well as evaluating options under broad or non-existing constraints.

## METHODOLOGY

This paragraph presents a methodology which will guide the development of a conceptual approach toward completion of a combined arms stochastic simulation of combat at the battalion task force level. The term combined arms in this context refers to the intentional integration of both mounted and dismounted Infantry units in conjunction with Armor units operating under unified direction toward some objectives. These forces will be supported by their normal complement of systems that could include but not necessarily be limited to aerial platform, artillery, special electronic equipment, etc. The development of a broad methodology, at this point in time, is intentionally followed to insure maximum flexibility.

### Objectives

The following constitutes a listing of objectives to be accomplished in the course of this study:

- 1) Development and presentation of a methodology to guide combat developments toward accomplishment of the stated purpose.
- 2) Definition of the battalion as a combat system in terms of the functions of land combat.
- 3) Review of existing relevant models, to include, but not limited to, ASARS, SIAF, DYNTACS, DYNCOM and DYNTACS-X.
- 4) Development of the executive routine.

- 5) Expansion of the logic outlined in the executive routine to provide a detailed plan for final expansion and development of the desired program.
- 6) Specify, in the form of tasks, the methodology for completion of the computer model outlining areas requiring further development, if appropriate.

#### Research

In the course of work in related fields, thirty-two relevant documents have been gathered for this effort. To insure that all prior efforts in this field had been identified a request for bibliographical search was submitted to the Defense Documentation Center. Two separate search results, classified and unclassified, were received under Search Control #5679 and 5680. Together these bibliographies listed in excess of 1000 reports completed within the last 8 years with classifications up to and including secret restricted data. Review of these bibliographies has identified reports of relevance to the subject area which have been used and added to the bibliography. Although this large number of references would seem to provide adequate sources for research it must be recognized that critical connecting logic between various aspects of this problem do not exist and had to be developed in this study.

### Organization of Report

This thesis is organized into 6 chapters which sequentially accomplish the objectives specified above. Chapter II first describes the battalion system in terms of the functions of land combat and then concludes with the development of minimum essential measures of effectiveness and their application in this study effort. Chapter III reviews existing models to identify and select appropriate subroutines for further use. Chapter IV describes the development of the executive routine through discussion of system control, three phased development of the routine and demonstrated operation of the routine. Chapter V details the modifications to existing programs or those which must be developed to permit completion of the program. Chapter VI presents the conclusions and recommendations of the study.

### SUMMARY

An exhaustive justification of the development of the combined arms model has not been undertaken in this study. The role that such a model could play in research and development has been presented in Figure 1. The hypothesis has been carefully framed to permit the development and evaluation of a conceptual modeling approach. This chapter defines the system of interest, outlines the tasks and methodology to be applied, and concludes

with an outline of the report.

## Chapter II

### THE BATTALION SYSTEM AND MEASURES OF EFFECTIVENESS

#### GENERAL

Although the term "battalion" defined in Chapter I is broad enough to include all organizations of interest, it is necessary to describe more precisely this complex system in terms of its basic components. This detailed specification is mandatory if the model to be built will have the flexibility desired for the broad range of applications outlined in Chapter I. The pursuit of the detailed description must be undertaken with consideration of the intended application of the model, specifically the requirement that data from exercise of the model produce measures of effectiveness of the unit under investigation. This chapter first develops a detailed description of the battalion system in terms of the functions of land combat and then reviews and establishes tentative measures of effectiveness. These measures of effectiveness will be those considered minimum essential for this study to be used as periodic checks during the model development to insure that the required level of resolution is being achieved.

## THE BATTALION SYSTEM DEFINITION

Description of the battalion system defined in Chapter I can be approached irrespective of any specific combat arm branch (eg. Infantry, Armor, etc). Regardless of branch, the command and control functions of the battalion are the same. The manner in which a particular type battalion pursues its objective leads to different tables of organization and equipment and indeed often dictates task organization by the tactical commander. This combined arms model must be capable of simulating any task organization. To accomplish this modeling effort it is necessary to describe the battalion in terms of the functions of land combat in such a manner as to make the description independent of any particular combat arms branch.

### Functions of Land Combat

The five functions of land combat through which organizations of interest accomplish their purpose are specified in FM 100-5.<sup>1</sup> Explicit modeling of the functions of land combat can permit the model's application to a wide range of problems. Each of these functions is first defined by extracts from AR 310-5 and then its

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<sup>1</sup>Department of the Army. FM 100-5. Operations of Army Forces in The Field. (September 1968) para 803; p. 801

specific application to this study is described.

Intelligence. "The product resulting from the collection, evaluation, analysis, integration and interpretation of all available information which concerns one or more aspects of foreign nations or of areas of operations and which is immediately or potentially significant to military planning and operations."<sup>2</sup> For application in this modeling effort the preceding definition must be expanded to include an explicit noting that target acquisition (consisting of detection, identification and localization) is a critical subelement within the broader element of collection.

Mobility. "A quality or capability of military forces which permits them to move from place to place while retaining the ability to fulfill their primary mission."<sup>3</sup> There is no need to expand on this definition.

Firepower. "The amount of fire which may be delivered by a position, unit or weapon system."<sup>4</sup> No expansion on this definition is required.

Command, control and communications. This func-

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<sup>2</sup>Department of the Army. AR 310-25, Dictionary of United States Army Terms. (June 1972), p. 277.

<sup>3</sup>Ibid., p. 337.

<sup>4</sup>Ibid., p. 221.

tion is not defined in its complete form. The first portion, Command and Control, is defined as "the exercise of authority and direction by a properly designated commander over assigned forces in accomplishment of his mission."<sup>5</sup> Although implied in the definition, the term Command and Control specifically includes integration of the efforts at accomplishing the other functions. Communications, defined as "a method or means of conveying information of any kind from one person or place to another, except by direct unassisted conversation or correspondence through nonmilitary postal agencies"<sup>6</sup> requires expansion. For purposes of this study, communications must include all transfer of information by any means.

Combat service support. Defined as "the assistance provided operating forces primarily in the fields of administrative services, chaplain services, civil affairs, finance, legal services, health services, etc.."<sup>7</sup> this term will be applied in its broadest sense and includes all necessary administrative support.

The battalion system. This system accomplishes its purpose through application of the functions of land

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<sup>5</sup>Ibid., p. 127.

<sup>6</sup>Ibid., p. 132.

<sup>7</sup>Ibid., p. 125.

combat. This relationship is shown in Figure 2. This figure depicts the battalion system as consisting of four subsystems: Intelligence, Operations, (to include Fire-power and Mobility) Combat Service Support and the integrating Command and Control system. The subsystems are interconnected by Communications. The modeling approach for the combined arms model will concentrate on each of these subsystems as they accomplish their purposes through the application of those relevant functions of land combat previously defined. The Command and Control or integrating subsystem is the executive routine or nerve center of the combined arms model.

#### MEASURES OF EFFECTIVENESS

##### General

At this point in the study it is necessary to "step back" and identify the overall purposes to be served by the model. Such an undertaking is required to enable the specification of essential information to be used in subsequent analysis and for the program's development. The conceptual application of the study to address the objectives characterized in Figure 1 of Chapter I will require the capability that the analyst be able to evaluate or measure the effectiveness of the unit as a whole while retaining the capability of evaluating the contribution of at least its major component parts. This approach is feasible if the system is defined and viewed

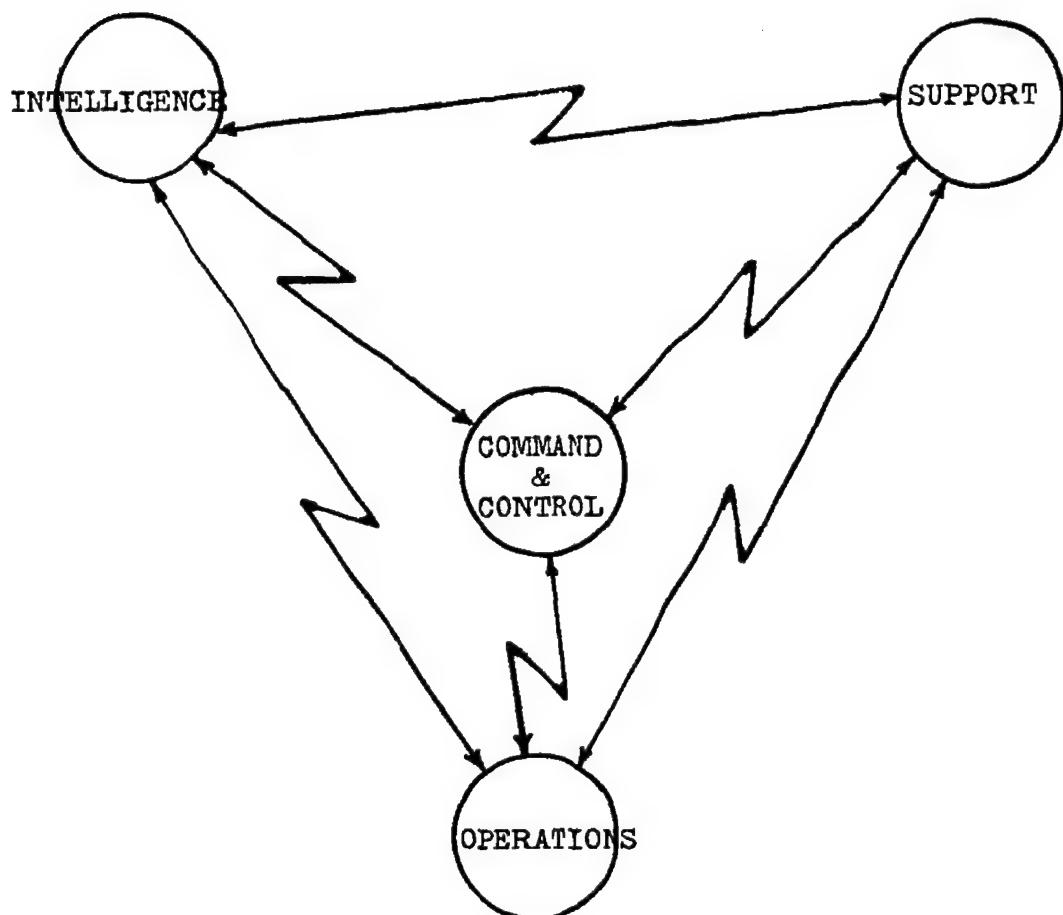


Figure 2  
The Battalion System<sup>8</sup>

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<sup>8</sup>Major Joseph F. Paone, "Computerized Automation and The Combat Leader," Infantry, (May-June 1972), 52-54.

through the functions of land combat previously described. The developer must exercise restraint in development of these measures as the temptation is ever present to develop large numbers of very specific measures, to the detriment of the overall program by creating an unmanageable myriad of detail. The measures subsequently developed must contribute toward evaluation of component effectiveness while not detracting from the overall usefulness of the program. Such an evaluation at this point in time will necessarily be judgmental but upon completion and application of the model, can be evaluated statistically to insure that each measure is carrying a load worthy of the effort required in satisfying the data requirement of each.

In the course of development of measures of effectiveness (MOE) it must be recognized that the system and measures of effectiveness of the system are necessarily interactive. Due to the nature of the system under investigation the interactive nature of the measures cannot be totally avoided. Measures must be developed in a manner that will minimize major interaction. The primary measures subsequently developed will comply to this design. It should be recognized however, that supplementary MOE to permit discrimination which exists only in areas displaying interaction may necessarily have to be developed and used.

A point that is often discussed at great length

by model developers is which specific measures of effectiveness should be finally selected. The term "minimum essential" has been used earlier in this chapter and the rationale for development of the measures at this point in time has been specified. These measures should not be viewed however as final. A large (relatively speaking) number of measures will be developed and considered the minimum essential for purposes of guiding the program design. They will be selected in such a manner as to enable expansion (if dictated for some specific objective) or reduction subsequent to some statistical evaluation. In general the application of these measures will be as shown in Figure 3.

The analyst should insure that the larger history of the battle set includes all the data that would possibly be required for MOE satisfaction. The specification of MOE at this point in time are considered those that are most demanding in terms of simulation development. The remainder of this chapter develops the required MOE for each function.

#### Intelligence

The function of intelligence was defined earlier as the product resulting from the collection, evaluation, analysis, integration and interpretation of information which concerns one or more aspects of foreign nations or of areas of operations and which is immediately or poten-

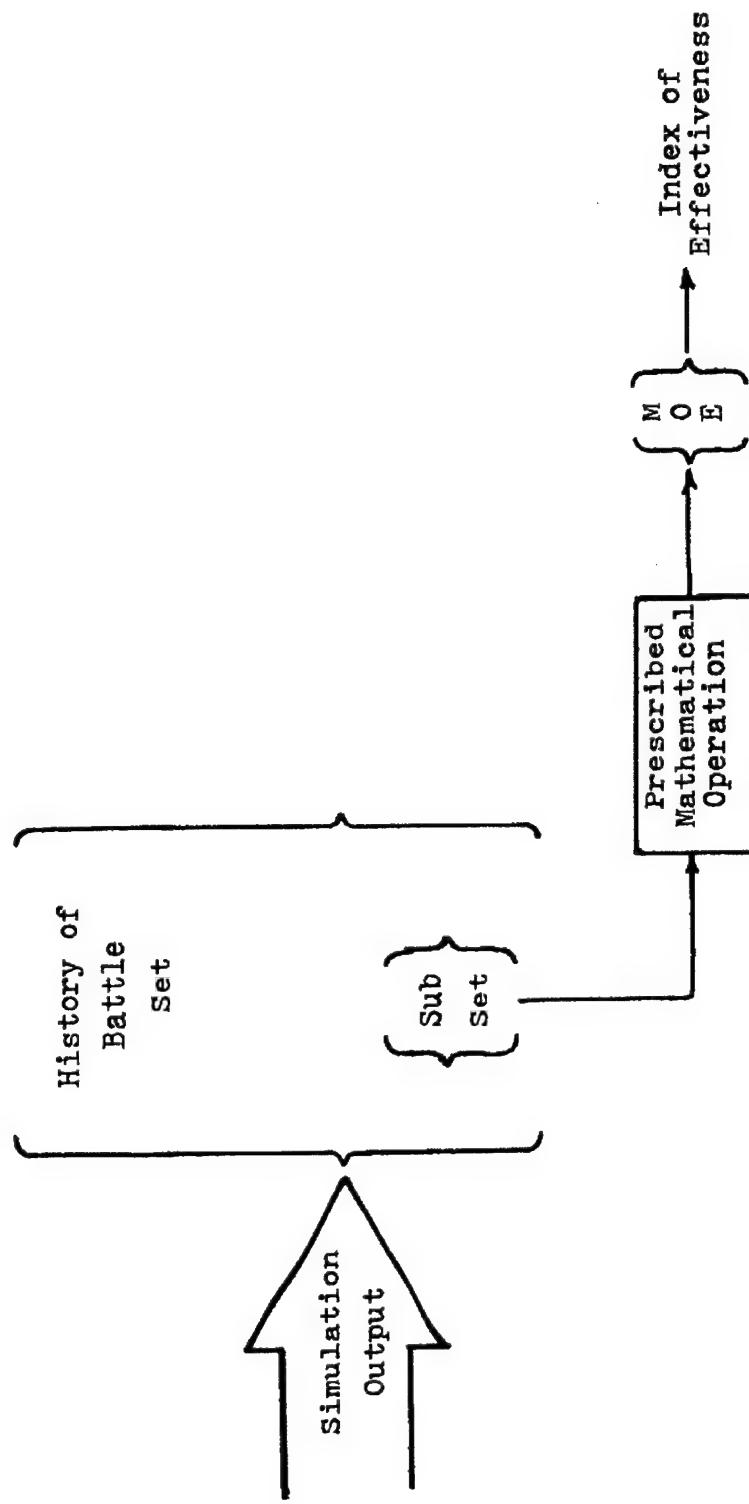


Figure 3  
General Application of MOE in a Study

tially significant to military planning and operations. Prior to the development of any potential measures of this function the operation and interaction of the elements of intelligence must be described. Figure 4 depicts this interaction which results in the product of combat intelligence. As described in FM 30-5 this combat intelligence is applied "to minimize uncertainty concerning the effects"<sup>9</sup> of the factors shown in the accomplishment of the mission. The realization of this reduction in uncertainty is the object of any measurement of the effectiveness of the intelligence function. The term uncertainty as applied in this study must be constrained to some lack of information from the total information that is available, and does not include subjective feelings on the part of the decision-maker.<sup>10</sup> Within these constraints an immediate relevant measure will be one that relates enemy information known or assumed, to that available. This measure will be called "intelligence comprehensiveness (completeness)" defined as the ratio of known information to total available. To permit discrimination between input variations in the form of systems or doctrine/procedures this measure must be related to time.

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<sup>9</sup>Department of the Army. FM 30-5, Combat Intelligence, (February 1971), p. 2-1.

<sup>10</sup>For the role of subjective feelings in the decision-making process see: Howard Raiffa, Decision Analysis (Massachusetts: Addison-Wesley, July 1970), pp. 104-105.

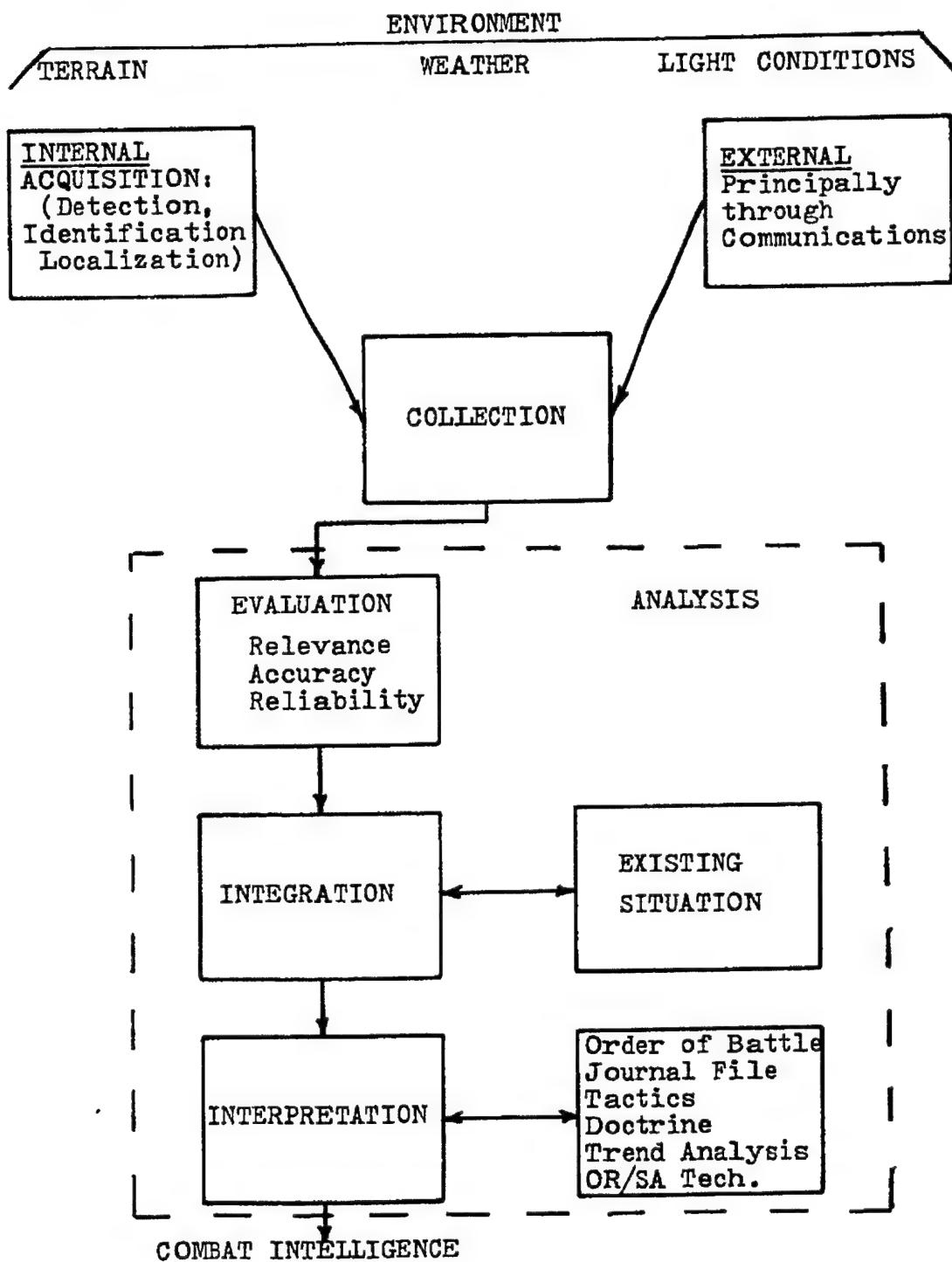


Figure 4  
Intelligence Function

This is an evaluation in recognition that accurate and timely intelligence reduces uncertainty.

There are numerous points within the processing procedure described in Figure 4 at which measures could be applied for a specific purpose. In recent years, considerable effort has been directed toward the internal element of collection, specifically acquisition. This action has been prompted by the host of Surveillance, Target Acquisition and Night Observation (STANO) devices entering the inventory. An increasing degree of interest is now being turned toward the internal analysis operations in current development efforts in support of the Tactical Operations System (TOS) and Integrated Battlefield Control System (IBCS). As appropriate, and as needed, additional measures contributing to the overall accuracy or timeliness can be added.

#### Combat Service Support

This functional area permits the capability of introducing an extremely large number of measures of effectiveness. Within the constraint of overall evaluation however, this function affects unit combat effectiveness in terms of whether it can support the intended operation or must restrict its prosecution. Each of the internal elements of this functional area can be evaluated in this same manner or the resolution can be re-

tained at its highest level. To satisfy the need in this functional area, a record of the number of times that optimum logic for actual combat operations (the best possible) has been restricted due to a shortage of some supply by class will be recorded. This measure of effectiveness will be called "measures of supply shortages." Explicit modeling of the medical evacuation and transportation within the battalion must be carefully evaluated to determine if the anticipated capability to address these functions are worth the expansion required.

#### Mobility

This function has been defined as the ability of a force to move from place to place while retaining the ability to fulfill its primary mission. Measurement of this function is simple, on the surface. Insight into the contribution of this function to unit effectiveness can be gained by a measure of the unit's "rate of closure" defined as the time required for the attacker to close on the defending force's position and terminate the engagement. This measure however, only partially covers the contribution made by mobility. For example, a force having a relatively higher capability of mobility than his opposition is offered a wider variety of courses of action from which to select, essentially greater flexibility. To properly assess this property of a unit it,

like combat service support, can be evaluated as a constraint. "Mobility restriction of action," defined as the number of times that a course of action was restricted due to lack of mobility, will also be used to more fully measure this function.

#### Firepower

The measures necessary to evaluate this functional area are relatively common and have been subjected to intensive investigation. A convenient compendium of this research effort is provided by a coordination draft published 29 February 1972 by Combat Developments Command Infantry Agency entitled MOE for Use in ASARS II and by the later publication in August 1972 of the final MOE for Use in ASARS II. These references provide a convenient review of the pertinent literature through 1972 and, as such, will serve as a point of departure. The thirteen primary MOE selected for use in the ASARS study reflect the detailed resolution required for that study.<sup>11</sup> Although it would be desirable to retain the same level of resolution, such an endeavor with our organization of interest would require an exorbitant size of computer storage capacity or an extensive and time consuming

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<sup>11</sup> U.S. Army Combat Developments Command Infantry Agency. MOE for Use in ASARS II, August 1972. (Fort Benning, Georgia: 1972), Incl. 4, pp. 4-1 to 4-5.

overlay technique. The resolution of this model can reasonably be lower, dealing with Infantry organizations of about squad size, tanks, artillery pieces and aerial platforms as opposed to the individual resolution of the ASARS II program. In evaluation of battalion systems, time and space and their associated measures take on increased importance over that associated with small unit and individual levels. In application of these measures it will be necessary that the analyst recognize the interaction of firepower with the other functions of the entire system. Prior to the employment of some fire system, target information will have to be processed by the intelligence subsystem and possibly communicated to the firing unit. Effectiveness measurement of the firepower function must be restricted to the delivery of fire and the effects of this delivery. The following factors offer such a measurement:

1. Number of rounds, by class, to first hit.
2. Number of hits per engagement.
3. Number of different targets hit.
4. Opening engagement range.
5. Range at which first hit occurred.
6. Blue casualties.
7. Red casualties.
8. Blue casualty rate.
9. Red casualty rate.

10. Percent of time that blue maintained fire superiority.
11. Red suppression of blue in Observation, Movement and Fire (OM & F).
12. Blue suppression of red in Observation, Movement and Fire (OM & F).

Command, Control and Communications

Although treated as a single function, communications can be measured as a component separate from command and control. Communications has been defined as the transfer of all information. This transfer of information can take place over the conventional radio and wire means but must also provide for that communications (informative) acquired visually. A decision-maker should be expected to acquire information through his own senses, within their limits, particularly if the more sophisticated systems are not responsive to his needs. In the preceding cases of radio and wire, accuracy and speed are the two most relevant measures of the communications systems' effectiveness. Accuracy can be measured explicitly in the act of transmission. The true meaning of accuracy has greater relevance toward the decision-making process than communications. To preclude a redundant measure of accuracy, this variable will be assessed in the command and control area. Speed of transmission is a measure

that should be undertaken for this functional element. The time to be measured is that average of time required by type transmission (enemy, status of own forces and tactical) from the time that the decision is made to transfer the information until the time at which the information transfer has been completed.

In the area of command and control attention is immediately directed to the process of decision-making. The decision-making process of interest in this study can more specifically be described as decision-making under conditions of uncertainty. The uncertainty is introduced by real-world constraints which recognize that decisions are made under conditions of varying degrees of imperfect information due primarily to constraints of time. Indeed, all the functions previously discussed contribute to the decision-making process. Howard Raiffa of Harvard University lists five steps to "roughly" describe this decision-making process.<sup>12</sup>

1. List of viable alternatives.
2. List events that may occur.
3. Arrange in chronological order the information you may acquire and the choices you may make as time goes on.
4. Decide how well you like the consequences that

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<sup>12</sup>Raiffa, op. cit., pp. ix-x.

result from the various courses of action.

5. Judge what the chances are that any particular uncertain event may occur.

This decision-making process can be portrayed as shown in Figure 5.

This examination of the decision process recognizes that virtually all decisions of interest in this certainty is either a function of requirement for a decision prior to the availability of additional information or due to inaccurate or outdated information being applied in the decision-making. An appropriate measure of this uncertainty called "risk" is defined as the ratio of known to actual information, where total information is unity and no information is zero. Provisions for a negative sense must be included to provide for incorrect information.

The second major factor in Command and Control is that of span of control. It is recognized that any commander, like an executive in business, decreases in his efficiency and effectiveness in the decision-making process as his span of control exceeds some point. The development of detailed measures to evaluate span of control, or to assess the point at which effectiveness begins to drop off in the decision-making process, is beyond the

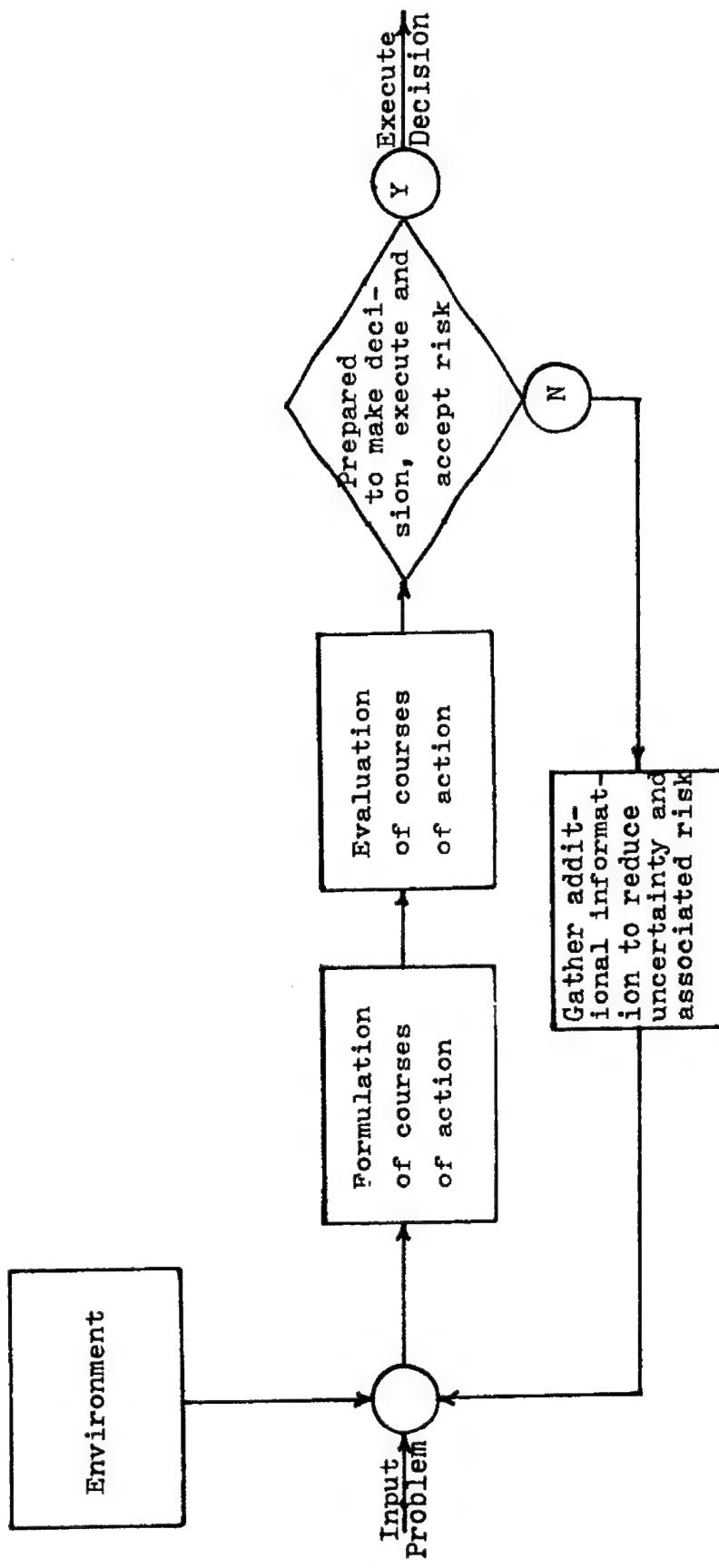


Figure 5  
Decision Making Process<sup>13</sup>

<sup>13</sup>Office of the Chief of Research and Development, Department of the Army. Proceedings, Eleventh Annual U.S. Army Operations Research Symposium. (North Carolina: 1972), p. 63.

scope of this study. For purposes of this effort it is sufficient to acknowledge that some point of reduced efficiency does in fact exist. As the number and complexity of subordinates reporting to the decision-maker increase the volume of data presented to the decision-maker will increase. It remains for the decision-maker to convert the data into information needed for the decision process. It could be expected that a decrease in effectiveness would result in higher risk than that experienced under a decreased span of control. It is suggested that "risk" in conjunction with time are appropriate measures of command and control effectiveness. Both of these measures are ordinal in nature in that they are useful only when compared to some previously derived value. The analyst can infer effectiveness for example when noting that some decision was made sooner or with relatively less risk than under some other circumstances. The capabilities and limitations of the commander and his organization can be enhanced or overcome through the application of standard procedures, staffs, or sophisticated, new equipment. These aids normally attempt to reduce either risk or time in the decision-making process. "Time," to be measured in this case, is that time from the point that the requirement for a decision to be rendered is identified to that point at which the decision is made.

## SUMMARY

This chapter has defined the battalion system and the functions of land combat in detail to facilitate their future use in the course of model development. Drawing attention to the danger due to the interactive nature of MOE, a listing by functional area was developed to serve as a preliminary screen during the course of model development. These MOE will be applied to insure the required level of resolution is achieved. In the interest of controlling the eventual size of the simulation, combat service support has been treated as a constraint on the ability of the unit to apply force on the battlefield. The results of this narrowing of scope has been a far greater number of firepower related measures than the apparently single measure of combat service support. This is reasonable when it is realized that the other functions impact on the capability of the force to develop and apply firepower. The measures selected are listed by functional area below:

1. Intelligence:

- a. Comprehensiveness at preselected points of analysis.

2. Combat service support:

- a. Measures of supply shortages.

3. Mobility:

- a. Rate of closure.

b. Mobility restriction of action.

4. Firepower:

a. Number of rounds, by class, to first hit.

b. Number of hits per engagement.

c. Number of different targets hit.

d. Opening engagement range.

e. Range at which first hit occurred.

f. Blue casualties.

g. Red casualties.

h. Blue casualty rate.

i. Red casualty rate.

j. Percent of time that Blue maintained fire superiority.

k. Red suppression of Blue in OM & F.

l. Blue suppression of Red in OM & F.

5. Command, control and communications:

a. Time for transfer of information by type.

b. Risk.

c. Time in decision-making.

## Chapter III

### REVIEW OF EXISTING MODELS

#### GENERAL

As stated earlier, the need for a battalion level stochastic simulation of combined arms combat is well documented and pursuit of this point further in this study will not be undertaken. The first major documented effort in the development of such a model was undertaken in September 1967 by the Combined Arms Research Office (CARO) of Booz Allen Applied Research Inc. under contract to U.S. Army Combat Developments Command. The final report covering this effort included a comprehensive review of models in the Department of Defense and identified those holding potential for application as combined arms models.<sup>1</sup> Of the 106 simulations reviewed at that time, seven were selected for closer evaluation.<sup>2</sup> The results of the CARO analyses have been reviewed and are considered valid and further detailed analysis of the seven relevant models will not be undertaken in this

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<sup>1</sup>U.S. Army Combat Developments Command. Combat Arms Model. Completed under contract by Booz Allen Applied Research, Inc. (Fort Leavenworth, Kansas: 31 May 1968)

<sup>2</sup>Ibid., p. 19.

study. The conclusions drawn by CARO with respect to the programs of interest will be used as a point of departure. Relevant points of evaluation of the seven models will be stated and a more detailed review of the development of programs subsequent to the May 68 report will be undertaken. In November 1970, The Institute of Combined Arms and Support Research Office (ICASRO) submitted a proposal to the U.S. Army Combat Developments Command, Combat Arms Group,<sup>3</sup> to develop a program which would permit a "rapid response capability to evaluate quantitatively cost effectiveness and cost/performance trade-offs."<sup>4</sup> This later proposal suggested the use of the Night Vision Combat Simulation (developed for the Electronic Command of AMC) as a base to accept selected portions of other models in approximating the major factors present in battalion level combat. Neither of these previously referenced efforts have successfully been followed through to completion but do contribute to this effort by evaluating programs and presenting alternative concepts.

The remainder of this chapter will review programs considered relevant to the study effort and draw general conclusions resultant from this review with

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<sup>3</sup>Booz Allen Applied Research Inc. Institute of Combined Arms and Support Research Office. Proposal: Combined Arms Battalion Level Evaluation (CABLE) (Kansas City, Missouri: 17 November 1970)

<sup>4</sup>Ibid., pp. 1-2.

respect to the overall modeling approach as well as potential use of these programs in development of the combined arms battalion system model.

#### REVIEW OF SELECTED PROGRAMS

##### CARMONETTE

Computerized Monte Carlo mathematical simulation of ground combat.

Background. The CARMONETTE model was first developed by the Operations Research Office of Johns Hopkins University. One of its earlier uses was in support of a 1962 study to evaluate the effectiveness of helicopter-borne antitank systems. Original work on the program can be traced back to the Los Alamos Scientific Laboratory in World War II and as such is considered the origin of ground combat simulations.<sup>5</sup> Since its development the CARMONETTE model has been used in several major studies and most of them have necessitated major revision to the original model. The first fully documented model is named CARMONETTE III. The roman numeral III was assigned

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<sup>5</sup>Research Analysis Corporation. CARMONETTE III Documentation Volume I General Description. (McLean, Virginia: 1967) p. 3. "The Monte Carlo mathematical simulation derives its name from the Casino at Monte Carlo. An earlier proposed simulation of ground combat was given the acronym CARMON, an inversion of the first syllables of the words Monte Carlo. The diminutive of CARMON - CARMONETTE - is the name of a much-reduced version of the original concept produced to avoid exceeding the capacity of current computers."

simply because of two earlier identifiable stages of development.<sup>6</sup> A major application of CARMONETTE III was its support of the Small Arms Weapons Systems (SAWS) Study completed by the Infantry Agency of Combat Developments Command in 1965. CARMONETTE IV modified earlier versions to incorporate night vision devices and to include communications. CARMONETTE V covered the further modifications to incorporate special requirements for the Equal Cost Firepower Study.<sup>7</sup> In addition to the numbered versions described there were several intermediate alpha numeric versions, the most noteworthy of which was the Small Infantry Unit Simulation (SINUS). The SINUS program could be designated CARMONETTE IVA and was developed for application in the Infantry Rifle Unit Study (IRUS) completed in 1969 by the Infantry Agency of Combat Developments Command. The SINUS version of CARMONETTE incorporated logic for the treatment of the dual purpose weapon, ie. rifle/grenade launcher.

Strengths. Perhaps the greatest strength of CARMONETTE is its survivability as evidenced by its seniority and the wide variety and number of programs its exercise has supported. Over the years the program has

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<sup>6</sup>Ibid., p. 4.

<sup>7</sup>Research Analysis Corporation. CARMONETTE IV and CARMONETTE V, Coordination Draft (McLean, Virginia: 11 November 1971)

been modified to the point that it now treats, with varying degrees of completeness, most of the factors of significance on the battlefield. Limited documentation tracing the development of the model is available and a user is capable, given adequate time, to piece the logic of its development together.

Weaknesses. Although "length of service" has been listed as a strength it must also be considered a weakness. Due to constraints of technology at the time of original development, several drawbacks of the main program remain although newer generations of computers and related software development have overcome these technological constraints. Of particular importance to this effort is the treatment of terrain and need for detailed rules of engagement. Terrain is represented by squares which have assigned to them indices describing most of the military significant aspects.<sup>8</sup> The drawback is the requirement that the entire square exhibit characteristics represented by the indices. The assumption here is that the military aspects of the terrain are homogeneous within the square. Although the dimensions of the square can be varied a further constraint requiring that the grid square be large enough to contain the maximum sized unit of resolution being simulated restricts the use of this

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<sup>8</sup>CARMONETTE III, op. cit., p. 7.

option to overcome the gross terrain approximation.<sup>9</sup> The existing CARMONETTE programs also require that "the scenario...completely describe all the terrain...and contain explicit orders describing the desired behavior of each unit for the entire period to be simulated."<sup>10</sup> It is not considered reasonable to constrain the user by requiring that he dictate actions to be taken by opponents on the battlefield. These decisions are situation dependent and must be made based upon the then current state of knowledge if these decisions themselves are to be subject to analysis.

The Individual Unit Action Model (IUA)

Background. The IUA model is an outgrowth of the Small Unit Action (SUA) model developed by the Lockheed Missile and Space Company under contract to the Armor Agency of Combat Developments Command in 1965-66. In its early stages of development the SUA model was competing with the more complex DYNNTACS model under development by Ohio State University. DYNNTACS pursued a more detailed and time consuming modeling approach while SUA offered a usable model earlier which led to its selection for use in

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<sup>9</sup>Ibid., p. 7.

<sup>10</sup>Ibid., p. 8.

the first Tank, Antitank, Assault Weapons Study, (TATAWS). The SUA model was built for and used on the Combat Developments Command computer at Fort Leavenworth, Kansas. As mentioned, Booz Allen had been operating a Combat Arms Research Office under a contract of general support to Combat Developments Command with offices at Fort Leavenworth and several agencies of CDC. Due to this close affiliation, Booz Allen began work with the SUA model early in its developmental stages and made it operational for the CDC community. CARO subsequently modified it to suit specific needs and made major modifications to the program for use in TATAWS III and the Anti Tank Mix (ATMIX) studies. This latter version of the SUA was renamed the Individual Unit Action (IUA) model. Although the SUA/IUA model was originally accepted as a short term choice over DYNTACS, the familiarity of the CDC community, and particularly the computer support personnel, with the IUA has led to its extensive use in deference to DYNTACS. Based on the data generated by earlier runs of the program in support primarily of ATMIX, Dr. Seth Bonder, of the University of Michigan, developed a deterministic approximation of the IUA which has been named the Bonder IUA. This latest development has permitted the major characteristics of the program to be quickly applied in generating quick and economical answers to gross questions with respect to tank and anti-tank systems.

Strengths. Like CARMONETTE one of the major strengths of the IUA program is its acceptability. As a battalion level tank/antitank simulation, the IUA model is a good first approximation of this type of combat in a restricted environment. The program is operational, there are personnel experienced in the model use on hand and a screening model in the form of the Bonder IUA exists.

Weaknesses. The major weaknesses of this model are similar to those in CARMONETTE and are found in the manner of treatment of the environment and rigid decision rules. In the early development of the SUA model, assumptions were made to facilitate speedy development which now constitute restrictions in the model. Detailed aspects of terrain and weather are not explicitly modeled. The convenience grouping of dismounted systems as well as the stationary firing of tank systems are highly restrictive. This model should not be underestimated however, when it is understood that it served its purpose well and that in so doing has permitted the careful development of the DYNTACS family of models. One further significant drawback is the lack of detailed documentation of the IUA program.

#### FILTER and Brigade Level FILTER

Both of these models are deterministic and are

useful only where quick approximations of conflict outcome at company and brigade levels respectively, are required. Normally these results will be input to some higher level model or game. Due to the deterministic nature of these models detailed evaluation of many of the internal functions of a battalion cannot be undertaken.<sup>11</sup> These two models are not considered further.

The Model for Assessment of  
Combat Effectiveness (MACE)

Like the FILTER models, MACE is deterministic and lacks the ability for internal evaluation as required.<sup>12</sup> MACE was developed as a quick fix to satisfy a need in 1956 while MAFIA continued development. It is not considered further.

Maneuver and Firepower  
Analysis (MAFIA IV)

Background. MAFIA IV is primarily a deterministic model built by Combat Developments Command Institute of Advanced Studies. Work on the model began in 1965 and a final report of the MAFIA IV version was presented in 1967. The MAFIA IV model has not been exercised in support of any specific study although at least portions of this effort to model division/brigade combat have been

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<sup>11</sup>Combat Arms Model, op. cit., p. C-5.

<sup>12</sup>Ibid., p. C-11.

used by the Institute of Advanced Studies.

Strengths. MAFIA IV is described by its developers as a "first generation model."<sup>13</sup> This model presents a reasonable expected value approach to modeling of maneuver, firepower and command and control. The measures of effectiveness grouping of (1) rate and direction of movement, (2) enemy resources destroyed and (3) resources consumed to accomplish (1) and (2), promise the capability of using MAFIA IV, or its successor, as a check during the development of this combined arms model.<sup>14</sup>

Weaknesses. In addition to the deterministic aspect of this model, communications, intelligence and combat service support are not explicitly modeled. The treatment of the critical aspect of terrain is at best gross.

#### Dynamic Tactics Simulator (DYNTACS)

Background. The DYNTACS effort traces its origin to 1953 when Ohio State University initiated a technical research and development program with the Armor School.

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<sup>13</sup>U.S. Army Combat Developments Command Institute of Advanced Studies. Maneuver and Firepower Analysis Model - MAFIA IV - Part I - User's Manual. (Carlisle Barracks, Pennsylvania: 1967) p. 3 of letter of transmittal.

<sup>14</sup>Ibid., p. 1-2.

The first major contribution to the DYNTACS model as it is currently known was made with the publication of the 1966 Annual Progress Report.<sup>15</sup> This volume reported the progress achieved in definition of the tank system and presented a general description of the conceptual DYNTACS model. The completed DYNTACS model was presented in 1969, six years after its official initiation.<sup>16</sup> This first in the family of DYNTACS models is described in Figure 6. An important lesson in military model building can be learned from this early development effort. Earlier programs did not incorporate explicit modeling of communications. It was learned in the course of development that this lack of explicit modeling biased the model in favor of the defender to the point that it completely reversed the reasonably expected outcome of the engagement. The lesson here is that the interaction of the functions in the combat environment can cause some significant influences on the outcome of a battle that may not be readily apparent.

The DYNTACS model presented the research and development community with a highly sophisticated

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<sup>15</sup> Daniel Howland and Gordon M. Clark. The Tank Weapon System. Systems Research Group, The Ohio State University. (Columbus, Ohio: June 1966)

<sup>16</sup> Albert B. Bishop and Gordon M. Clark. The Tank Weapon System. Systems Research Group, The Ohio State University. (Columbus, Ohio: 1969) 4 volumes.

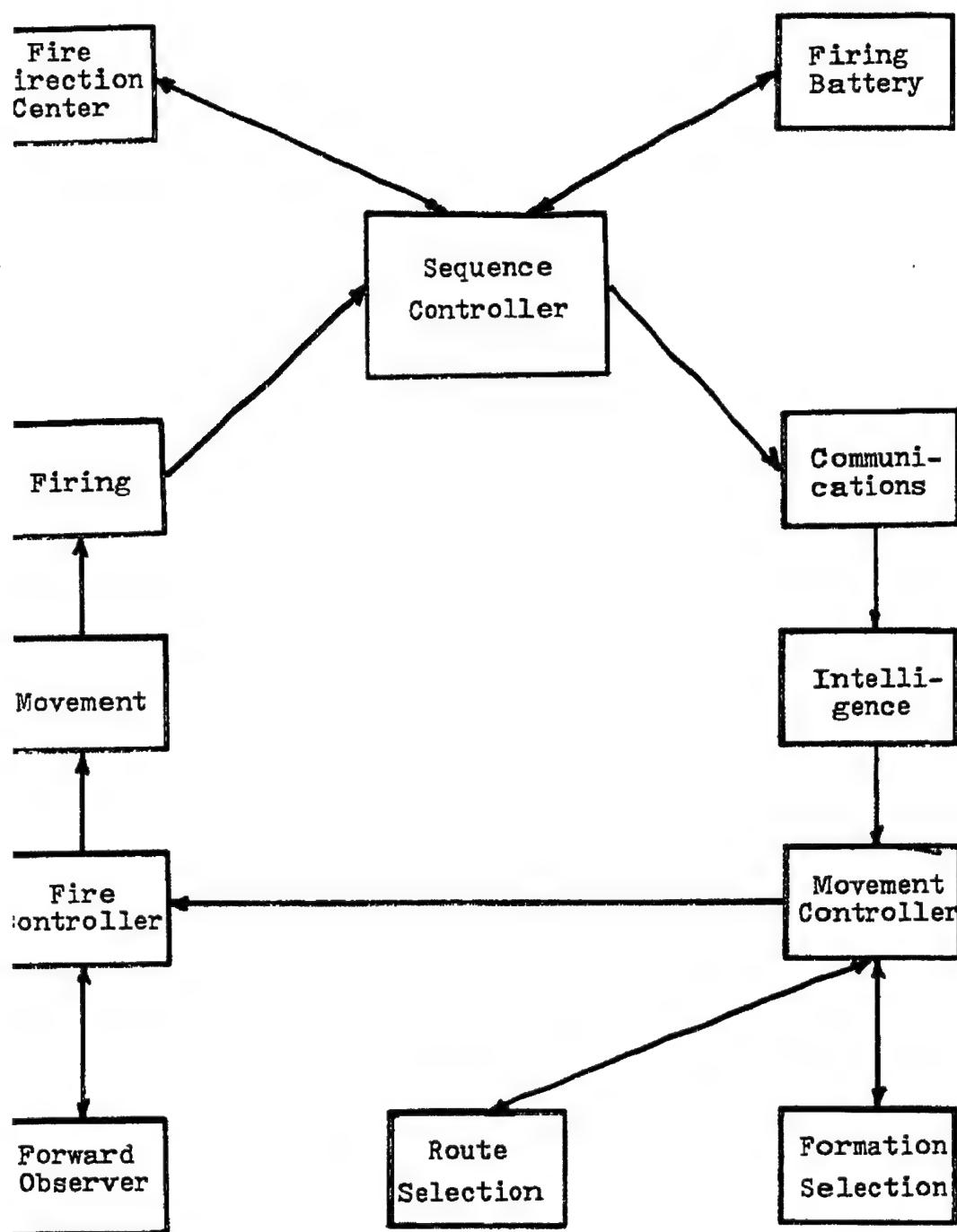


Figure 6  
DYNTACS Schematic<sup>17</sup>

<sup>17</sup>Ibid., vol. 4. p.27.

stochastic simulation of tank combat. In 1967 a program was initiated by U.S. Army Missile Command by contract with Ohio State University to develop a land combat model that would predict the effects of missile performance characteristics in ground engagements. The basic DYNTACS model was modified to incorporate sophisticated routines to evaluate the performance of various missile systems, including dismounted Infantry elements in a rudimentary sense and an Aerial Platform Module which represented combat activities of aerial vehicles.<sup>18</sup> The play of aerial platforms at this point in time was highly restrictive. It remained for the next and current DYNTACS refinement, DYNTACS-X, to develop the full set of aerial platform routines permitting evaluation of the contribution by aircraft to ground unit effectiveness. DYNTACS-X was developed by Ohio State University under contract to Combat Developments Command in support of the Hard Point Target Study. This study effort and its use of DYNTACS-X was subsequently discontinued but the work on the model continued and was completed in 1971. The progression then can be traced through 1971 by DYNTACS, DYNCOM and finally DYNTACS-X with the latter program incorporating aspects of artillery counterbattery fires, anti-aircraft fires

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<sup>18</sup>Gordon M. Clark, et. al., Land Combat Model DYNCOM Programmer's Manual. Research Analysis Group, The Ohio State University, (Columbus, Ohio: 1970) p. v.

and aggressive aerial platform engagement of ground targets.<sup>19</sup>

Strengths. In each stage of development, the DYNTACS family of simulations presented a significant advance in the state of the art. Treatment of terrain was far improved over anything presented earlier, decision logic in the intelligence and maneuver functional areas were revolutionary. A system of documentation was established which permitted an analyst to access any part of the program for more detailed evaluation without a time consuming journey through the entire model. This family of models presents a meaningful representation of the major mounted combat and combat support aspects of ground combat and, as such, are major contributors to the combined arms model.

Weaknesses. Three significant weaknesses of this family of models can be identified. The first weakness is the result of specialization toward satisfaction of some specific study objective. In the case of the DYNCOM development, space and time consuming detailed routines tracking the flight path of missiles were integrated into the program. The result has been a varying degree of resolution within the model at the cost of computer storage

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<sup>19</sup>Ibid., vol. 2A, p. v.

space and running time. The second weakness of the program is the inadequate treatment of dismounted or combined combat action. Although dismounted forces are played they cannot be treated with a level of sophistication commensurate with that of mounted forces. The third significant weakness is the size and sophistication of the program. This size and degree of sophistication have mitigated against the program's use, to the overall detriment of the program.

Small Independent Action Force (SIAF)

Background. Work on the SIAF program was initiated in 1965 by the Advanced Research Project Agency (ARPA) of the Department of Defense Research and Engineering (DDRE) at the direction of Congress and was to concentrate on the then expanding role of U.S. Ground Forces in Southeast Asia. There evolved a detailed investigation into all facets of small independent action forces of from two to twelve man size to describe and, to the extent possible, model this highly complex system. This program developed into a major undertaking involving many agencies of DOD and numerous contracts with civilian firms. Through 1972, when the program was transferred to the Department of the Army, an estimated 4.5 million dollars had been expended.

One of the earlier efforts in the SIAF field was

the development of an extensive data base. Principle effort in this area was accomplished by Vertex Corporation under contract to ARPA. Thompson-Ramo and Woolridge (TRW) was subsequently awarded a contract to develop a computer simulation of the SIAF action. The results of this modeling effort, culminating in 1972-73 with the publication of a draft user's manual,<sup>20</sup> presented a highly detailed and sophisticated modeling of the individual soldier in a SIAF role.

The SIAF model consists of two significant component parts: the reconnaissance and ground confrontation models. A schematic of the reconnaissance portion of the program is shown in Figure 7. The ground confrontation model is called by a master executive program to resolve confrontation of forces, if that option is selected, following execution of at least a portion of the reconnaissance model.

Strengths. The entire SIAF program presents an extremely well documented highly detailed modeling of the most complex element on the battlefield, the individual soldier. Modeling techniques in the area of terrain and detection significantly advanced the state of the art.

The data base provides a detailed compendium of information

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<sup>20</sup>TRW Systems Group. SIAF System User's Manual - Draft (Redondo Beach, California: 1972)

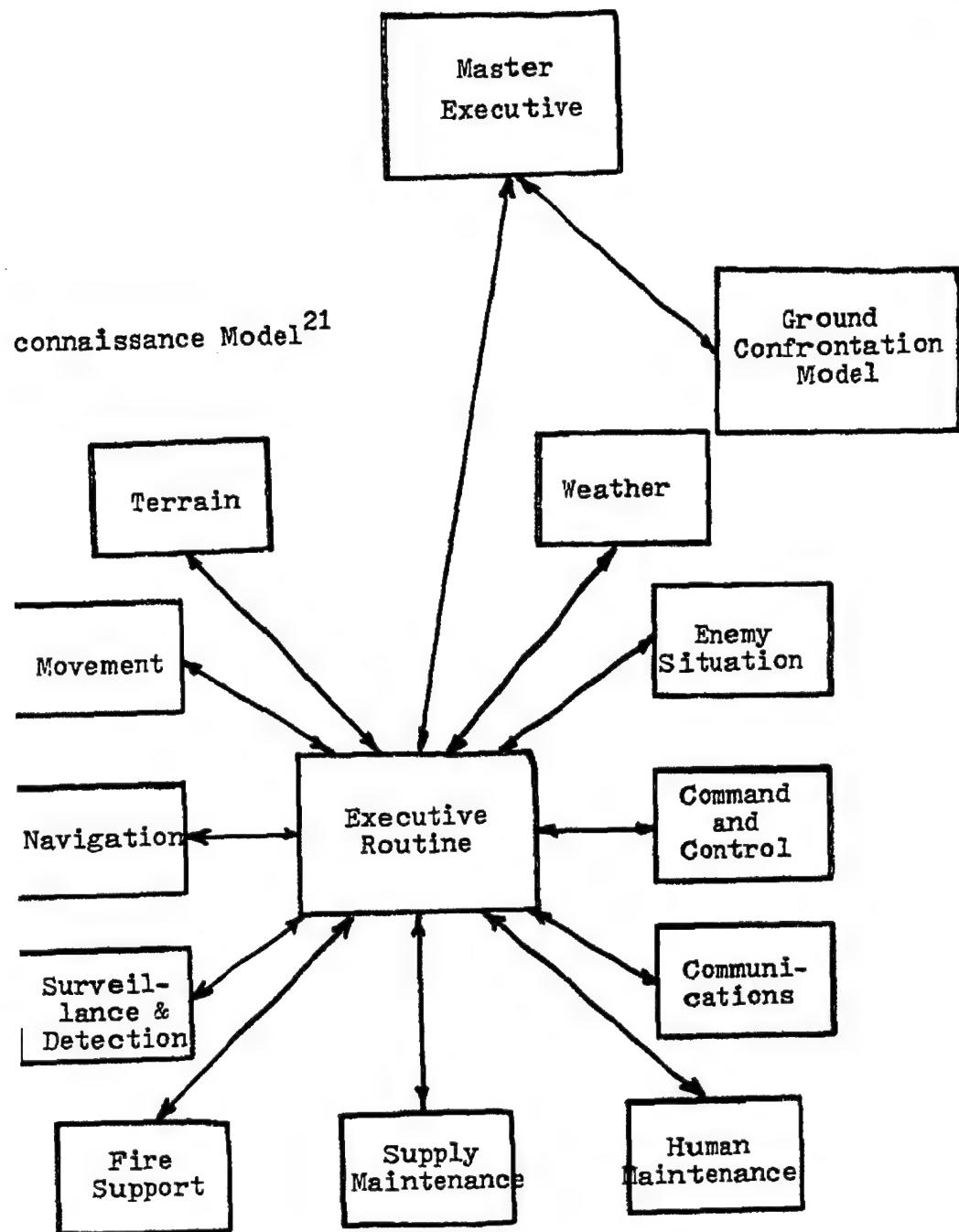


Figure 7  
The SIAF Program

<sup>21</sup> Ibid., p. 2-6.

to support model development in several related fields.

Weaknesses. Similar to the experience with the DYNTACS family the SIAF program's strength is also its weaknesses with respect to the combined arms model. The resolution and consequent detail of the SIAF program are very high. As a result of this detail the program in its current form requires four overlays to fit on the current CDC 6500 computer at Fort Leavenworth. This detail is not considered necessary for the combined arms model.

Army Small Arms Requirement  
Study (ASARS)

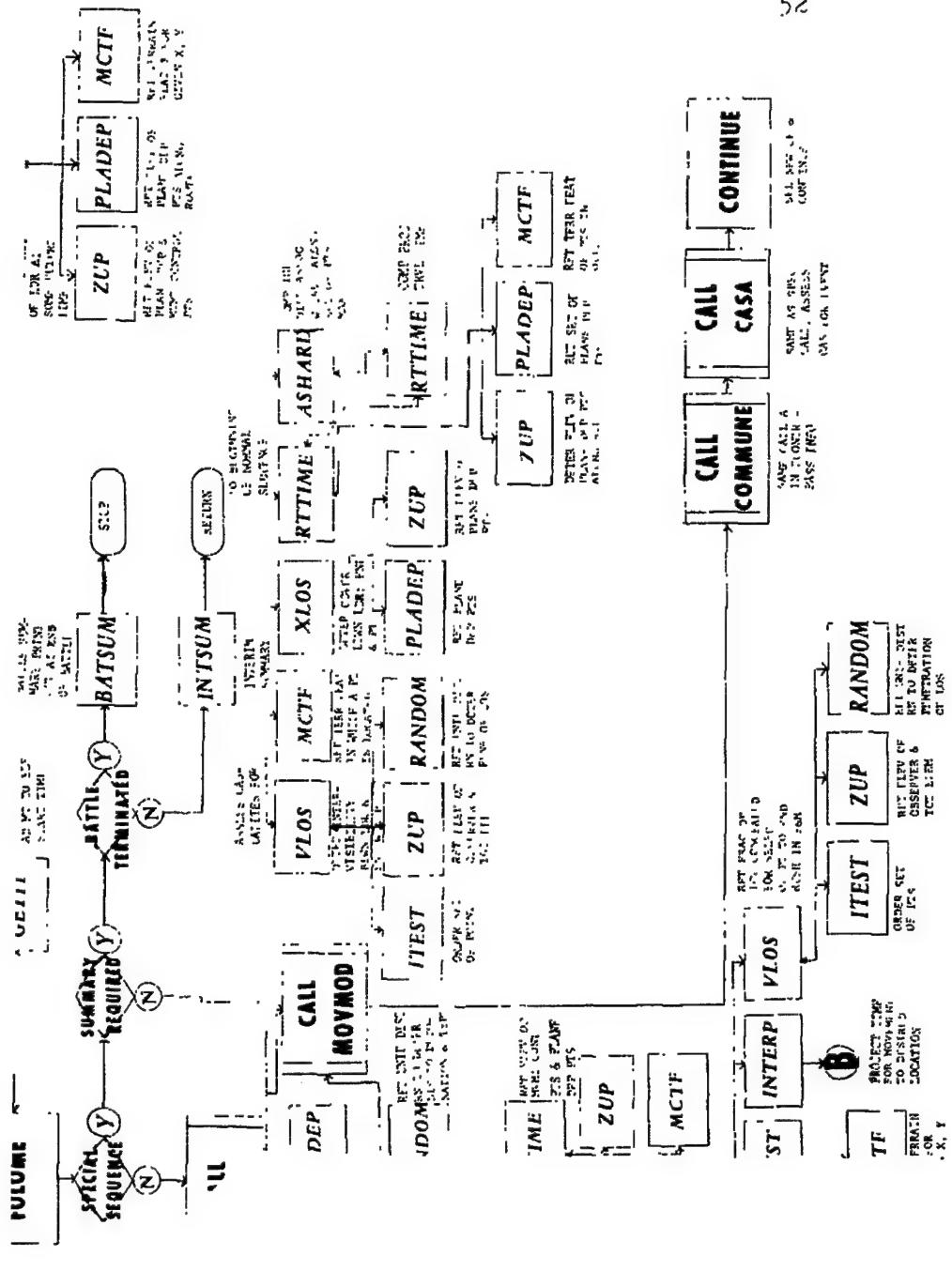
Background. The ASARS program traces its origin back to the Small Arms Weapons Systems study in 1965. In this early study, completed by the Infantry Agency of Combat Developments Command, the CARMONETTE model was exercised. The exercise of the CARMONETTE program identified a need for the development of a more advanced model to investigate the dismounted aspects of combat and led to the initiation of the ASARS program. In 1970 a decision was made to build a high resolution stochastic simulation of combat at the squad and platoon level. The task of model development within ASARS was undertaken by Systems Analysis Group of Combat Developments Command in support of the study proponent, the Infantry Agency.

The development of the ASARS Battle Model effectively integrated the more desirable concepts formulated in the DYNTACS and SIAF programs. The completion of the program by Systems Analysis Group was cut short by the reorganization of the Army in 1973, however, a ten volume report was prepared by the Group prior to its dissolution.<sup>22</sup> Although the program had not been fully completed it still represented a significant advancement in the state of the art and continued development of the program was undertaken by the Infantry School at Fort Benning, Georgia. Figure 8 depicts the execution logic of the ASARS Battle Model as of June 1972.

Strengths. The strengths of this program are far too numerous to adequately, or necessarily, list in this study. The explicit modeling of Intelligence, Operations, Command, Control and Communications was essentially accomplished. The results of an extensive research effort by Defense Science Laboratories of Litton Systems Inc. into the phenomenon of suppression were carefully integrated. The ASARS program effectively closed the gap existing between the SIAF and DYNTACS programs. Most significant however, is that the overall design of all three of these programs are essentially compatible and they are well documented.

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<sup>22</sup>U.S. Army Combat Developments Command Systems Analysis Group, ASARS Battle Model. (Fort Belvoir, Virginia: 1973)



Weaknesses. Although ASARS made a significant effort toward closing the existing gap all the objectives have not yet been fully realized. Dynamic fire and maneuver is not adequately modeled in any program existing today. Many aspects of the DYNTACS and SIAF programs have not been integrated into the ASARS model eg. artillery support and weather. These shortfalls are under study and concepts for their reduction have been prepared.<sup>23</sup> It is simply a matter of time and resources until they are completed.

#### Other Programs of Interest

The preceding subparagraphs have reviewed in some detail several existing models but could not reasonably include all models in existence. There are a number of additional programs that must be addressed due either to their popularity or because of their anticipated contribution, in part, to the combined arms model.

#### Stanford Research Institute (SRI) Firefight Model.

This is an expected value model that was developed by Stanford Research Institute. Although some stochastic processes have been integrated into the program, most notably by Operations Research Associates under contract

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<sup>23</sup>U.S. Army Infantry School. Army Small Arms.  
Requirement Study II (ASARS II) Fourth In Process  
Review, 21 June 1973, After Action Report (Fort Benning,  
Georgia: 29 June 1973) tab. F.

to ARPA, the model basically remains deterministic in design. The resultant limitations of the program are enumerated in detail by TRW in a portion of their report on the SIAF program.<sup>24</sup>

LIVFIR. This program was developed by the Litton Scientific Support Laboratory under contract to U.S. Army Combat Developments Command Experimentation Command at Fort Ord, California in 1969. LIVFIR is a deterministic model by design, although some stochastic processes are used in the decision-making process. The model was developed to approximate results of experimental firings at Hunter Liggett Military Reservation in support of the Infantry Rifle Unit Study and to assist in experimental design for future uses of the ranges.<sup>25</sup> Since that time however, several changes have been incorporated to attempt to adapt the program to other purposes. Its inherent limitations remain for purposes of this study.

EINFALL. (The German word for invasion). This model/war game was prepared by SRI for the German Ministry of Defense. This program is essentially a limited

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<sup>24</sup>TRW Systems Group. Addendum to Volume III, SIAF Organic Combat Model, Volume V (Redondo Beach, California: 1971)

<sup>25</sup>U.S. Army Combat Developments Command Experimentation Command. Handbook for LIVFIR - A Small Arms Target Range Simulation (Fort Ord, California: 1969)

access war game. Exercise of the program is controlled at preselected stages of the battle and the model is used to resolve these "frames" of combat.<sup>26</sup> The program itself is deterministic in design and has limited internal decision logic and limited play of terrain. Its meaningful application should be restricted to short duration conflict resolution in support of some gaming activity.

Analysis of Opportunities for the Reduction of  
Tactical Vehicle Requirements Through Pooling. This study was completed by Research Analysis Corporation and offers potential for application of portions of its efforts to modeling aspects of the combat service support function. In the interest of keeping the size of the combined arms model down to reasonable limits the results of this study could be applied to accept demands and project responses by the transportation systems at some preselected rear boundary of the battalion.

Aerial Weapons Effectiveness Simulation (AWES). Although DYNTACS-X and CARMONETTE address aerial platform systems their results cannot be considered, at this point in time, to be validated. The Aerial Weapons Effectiveness Simulation (AWES), developed by the Combat Operations Research Group under contract to U.S. Army Combat Develop-

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<sup>26</sup>Planning Research Corporation. Final Report on Sinfall I (Los Angeles, California: 1966)

ments Command provides another source of modeling this aspect of combat. It should be integrated with the other referenced sources in modeling the aerial platform.

The Duel-Model. This model was developed by the University of Alabama Research Institute under contract to the U.S. Army Missile Command and provides an alternative to the DYNTACS-X program for anti aircraft modeling.

The Service Support War Game. This war game was developed by the Combat Operations Research Group and has two submodels of potential value in the combined arms model development. The submodels of interest are the Rear Area Protection and Construction submodels. When dealing with force structures and areas of operation of battalion and brigade sizes these functions take on increased importance. The Service Support War Game programs present results of detailed analysis into these operational areas.

Airlift Simulation Study. The last major existing program of interest is the stochastic simulation developed by Headquarters Tactical Air Command in support of the Airlift Simulation Study. This program explicitly addresses aspects of aerial resupply which will support the modeling of portions of the combat service support functional area.

## CONCLUSIONS

As evidenced by the preceding evaluation of existing programs, extensive efforts by many different organizations have been directed toward solving a variety of very specific problems. The critical connecting link is that, for the most part, those programs selected pursued solution of their problems through the development and/or execution of stochastic models. These pursuits were directed toward at least a portion of the five functions of land combat described in preceding chapters. With the development of the ASARS Battle Model the missing piece in the combined arms puzzle (Infantry) has been sound and it remains to integrate all these efforts to realize a combined arms model. The remainder of this study is devoted to such an integration.

## Chapter IV

### EXECUTIVE ROUTINE

The executive routine is the control center of the model. The function performed by the executive routine in a computer simulation can be compared to that of the brain and the nervous system in the human body. The executive routine will select the elements and events to be processed, call appropriate subroutines to perform their designed function and transfer information. This chapter will develop the level of resolution required, describe the desired means of program control, define a grouping of major subroutines to be used in the course of model development and build the executive routine. The executive routine will be built in three phases. The first phase, Phase A, will develop the broad method of operation of the model by wargaming the battalion sized element. Using Phase A as a point of departure, Phase B will expand the logic to include tactical details of execution. The final phase, Phase C, will further expand this logic in FORTRAN IV, program and execute the model using dummy subroutines as necessary.

## RESOLUTION

Although it would be desirable to design a resolution at the individual soldier level, such an endeavor could quickly exceed any reasonable computer storage capacity. Resolution to the individual soldier was achieved in the SIAF and ASARS program. In the case of IAF the force simulated was by design limited to about twelve men while in the ASARS program the limit is reported to be about 150 elements. When ASARS is loaded with its full complement of 150 elements it is anticipated that the running time will increase significantly. This ASARS limit restricts the simulation to that of the committed elements of a dismounted rifle company (2 platoons) attacking a reinforced squad sized element conducting a defense. The DYNTACS and IUA programs apply a resolution at the individual tank level. For purposes of this study, in pursuit of the type objectives listed in figure 1 of Chapter I, the resolution used in the DYNTACS and IUA programs is considered adequate.

To insure compatibility across both functional areas and organizations undergoing evaluation, similar levels of resolution by branch must be specified. The establishment of a required level of resolution is considered important enough to warrant detailed evolution at this point. This process will also serve to illustrate potential study areas in which this program could be

pplied. These illustrations will reinforce the design guides developed earlier.

Type Task Force of Interest

The organization of interest is the combined arms unit of approximately battalion size. For purposes of this discussion a mechanized Infantry task force is selected for detailed expansion. In consonance with the earlier description of a combined force a basic mechanized Infantry battalion will be used with the replacement of one of the three mechanized Infantry companies with a tank company.<sup>1</sup> This action is normally taken by a brigade commander when he is allocating combat power and has both mechanized and Armor forces available. This action is called tailoring of a force to create two or more task forces. Such an organization is represented in Figure 9. The battalion commander, upon attachment of a tank company in exchange for a mechanized Infantry company, will normally cross attach his forces. This action serves to create three similar mechanized Infantry heavy teams which integrate the unique capabilities of both the Armor and Infantry forces. Caution is required at this point to ensure understanding that the similarity of these three teams is limited to the fact that they are major maneuver

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<sup>1</sup>Department of the Army. FM 7-20, The Infantry Battalion. (December 1969), p. B-4.

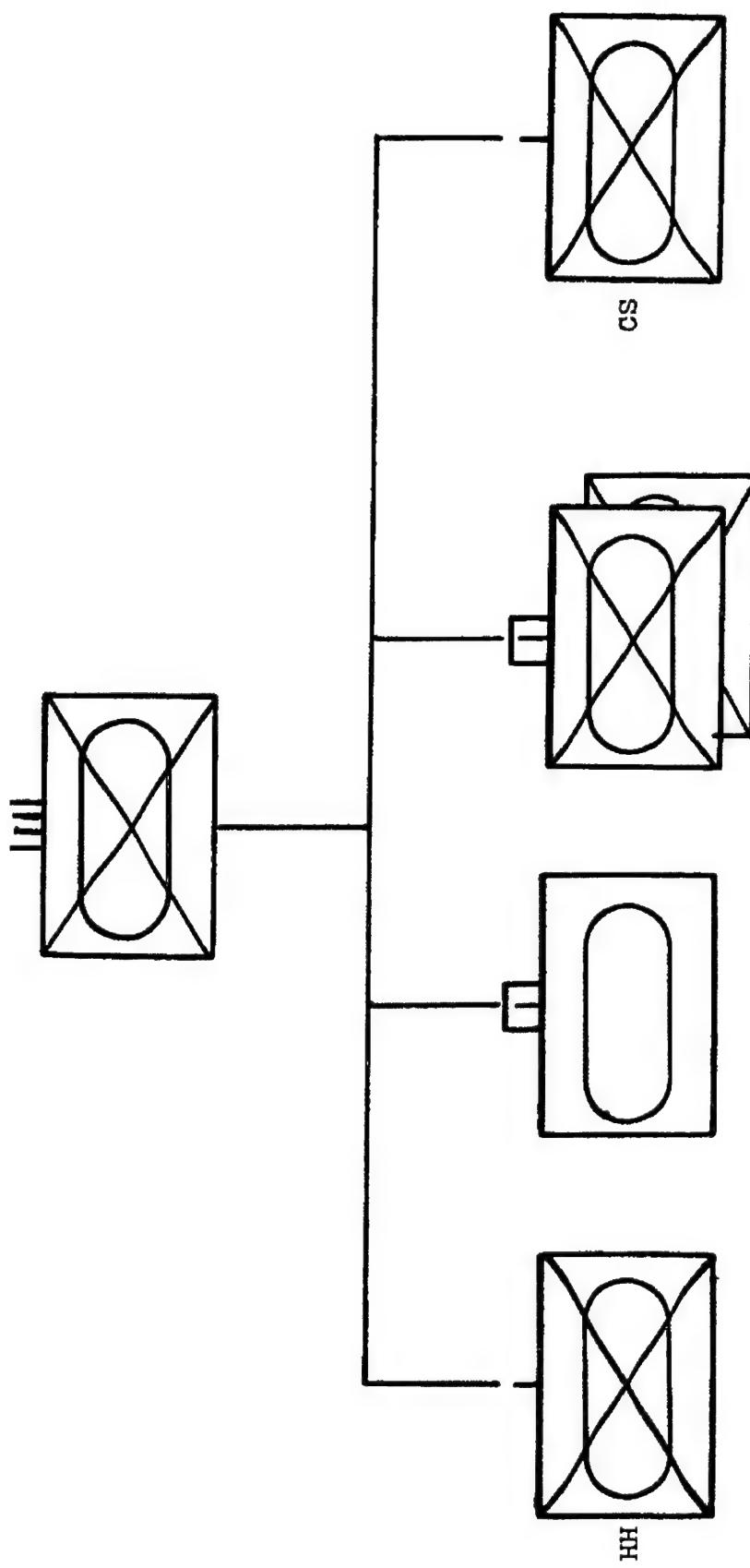


Figure 9  
Battalion Task Force

units.

#### Major Maneuver Units

Figure 10 represents the result of cross attachment of Armor and Infantry forces as directed by the battalion commander. A platoon of mechanized Infantry has been detached and replaced by the attachment of a platoon of Armor.<sup>2</sup> This organization should be carefully compared with that of the Armor company team shown in Figure 11. In Figure 11 the result of the battalion commander's task organization through the detachment of two tank platoons and attachment of two mechanized Infantry platoons has created a third mechanized Infantry heavy team.<sup>3</sup> Due to the basic organization of the tank company however, the Armor company team does not have the weapons platoon as shown in Figure 10 of the mechanized Infantry team. An equally significant but less obvious difference is in the maintenance and supply activities at company level. A significantly different capability in maintenance, evacuation and support exists between the two organizations.

These three team organizations constitute the major maneuver units of the battalion task force. It is

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<sup>2</sup>Ibid., p. B-4.

<sup>3</sup>Department of the Army. FM 7-15, Tank Units Platoon, Company and Battalion. (March 1966), p. 7.

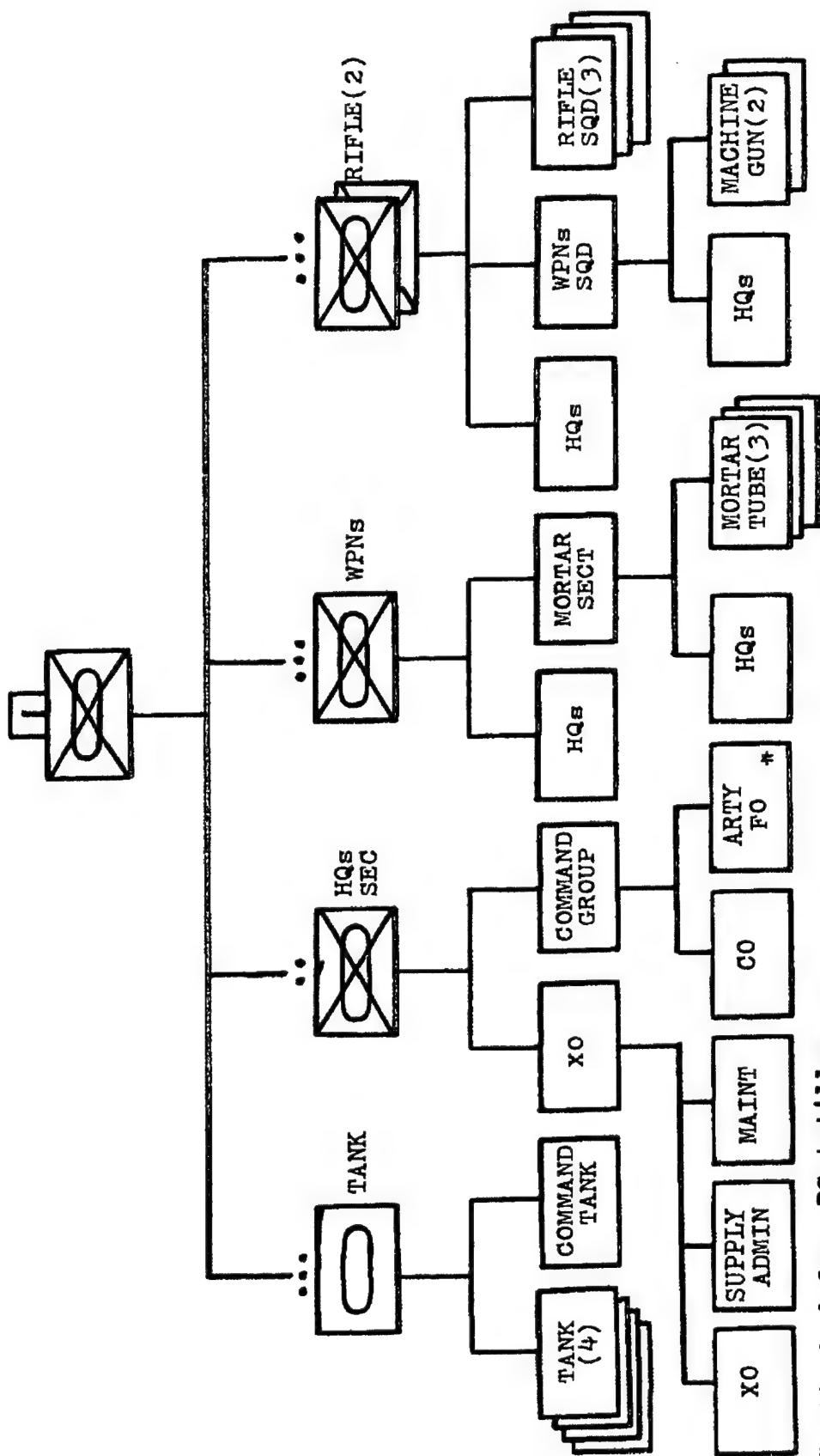
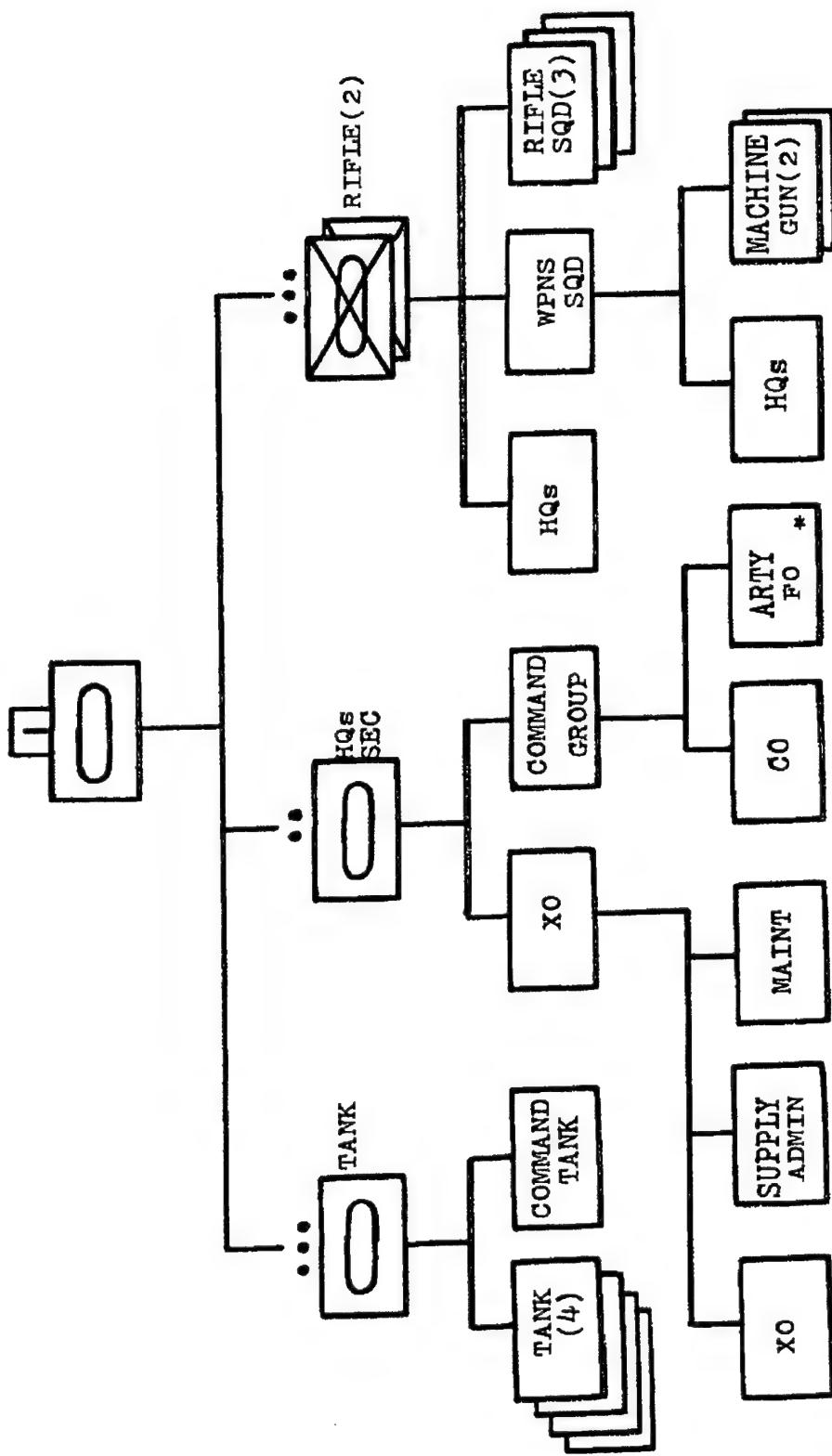


Figure 10

Mechanized Infantry Team Organization



\* Attached from DS Artillery

Figure 11

Armor Team Organization

through these forces that the task force accomplishes its assigned missions. The resolution at which these organizations are treated in the model is of particular importance.

These major maneuver units of the task force are the units in which we would expect to introduce expensive new weapon systems. Any future rifle system will be designed to enhance the combat effectiveness of the rifleman found at the squad level of these organizations. The required level of resolution within these organizations can be appreciated by recalling a recent, and as of yet not satisfactorily resolved, question with respect to the introduction of the new medium anti-tank weapon, Dragon. Considerable effort has been expended to determine whether the distribution of this new weapon should be implemented at the squad level by use of a "dedicated gunner"<sup>4</sup> or the "designated gunner"<sup>5</sup> concept. One factor which was a significant consideration was the level of training required on the part of the rifleman to achieve a desired level of proficiency with the Dragon system. This evalua-

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<sup>4</sup>The concept of the dedicated gunner visualized the reduction of one rifleman from the squad organization and his replacement with a Dragon gunner, trained and proficient in the use of the system.

<sup>5</sup>The concept of the designated gunner visualized application of the "arms room concept" where the weapon system would be stored on the squad Mechanized Infantry Combat Vehicle for use by a "designated" rifleman at the direction of the squad leader.

tion was assisted by data collected during the course of Expanded Service Testing of the Dragon system. An equally or perhaps more important aspect that could not be evaluated in a comfortable manner was the affect on unit effectiveness as a result of selection of either of these courses of action. This combined arms model must have a resolution capable of assisting decision-makers in making decisions as described in the preceding example. The question of manning of the Dragon system is not the last of these type problems to confront the military. Cost-effectiveness and tradeoff analyses presume an ability to evaluate at least relative combat effectiveness. At this point in time such effectiveness evaluation can only be approximated in a relatively sterile environment. The combined arms model must be capable of discrimination at the squad/tank level to adequately assist in resolving problems exemplified by the Dragon manning example.

Another group of elements requiring consideration are those headquarters that control the squad/tanks previously selected. Additional organizations within the company structure provide command, control and support of the subordinate units and should be specified as elements for explicit modeling. These additional elements include the commander, executive officer, supply and administration, maintenance and the artillery forward observer team. Although the artillery forward observer team is not a

part of the TO&E of the unit, it is habitually employed with the unit and should be modeled as an element.

Battalion Organic Combat Support

The next major unit shown under the assumed task force organization in Figure 9 is the combat support company. As its name implies the mission of the combat support company is to provide combat support to the task force and its major subordinate maneuver units. The combat support company of the mechanized Infantry battalion is organized as shown in Figure 12.<sup>6</sup> The combat support company has five major combat and combat support elements as shown in Figure 12. Each of these elements are organized in a similar manner in that they have a headquarters section and a variable number of subordinate units which perform the unique functions implied by their names. In addition to these elements, like the Armor and mechanized Infantry teams, the command, supply and administration and maintenance organizations should be treated explicitly and appear as elements.

Again referring to Figure 1 a conceptual application of the combined arms program can be visualized. Several considerations have exerted pressure for the elimination of mortars at company and battalion levels. These

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<sup>6</sup>FM 7-20, op. cit., p. B-3.

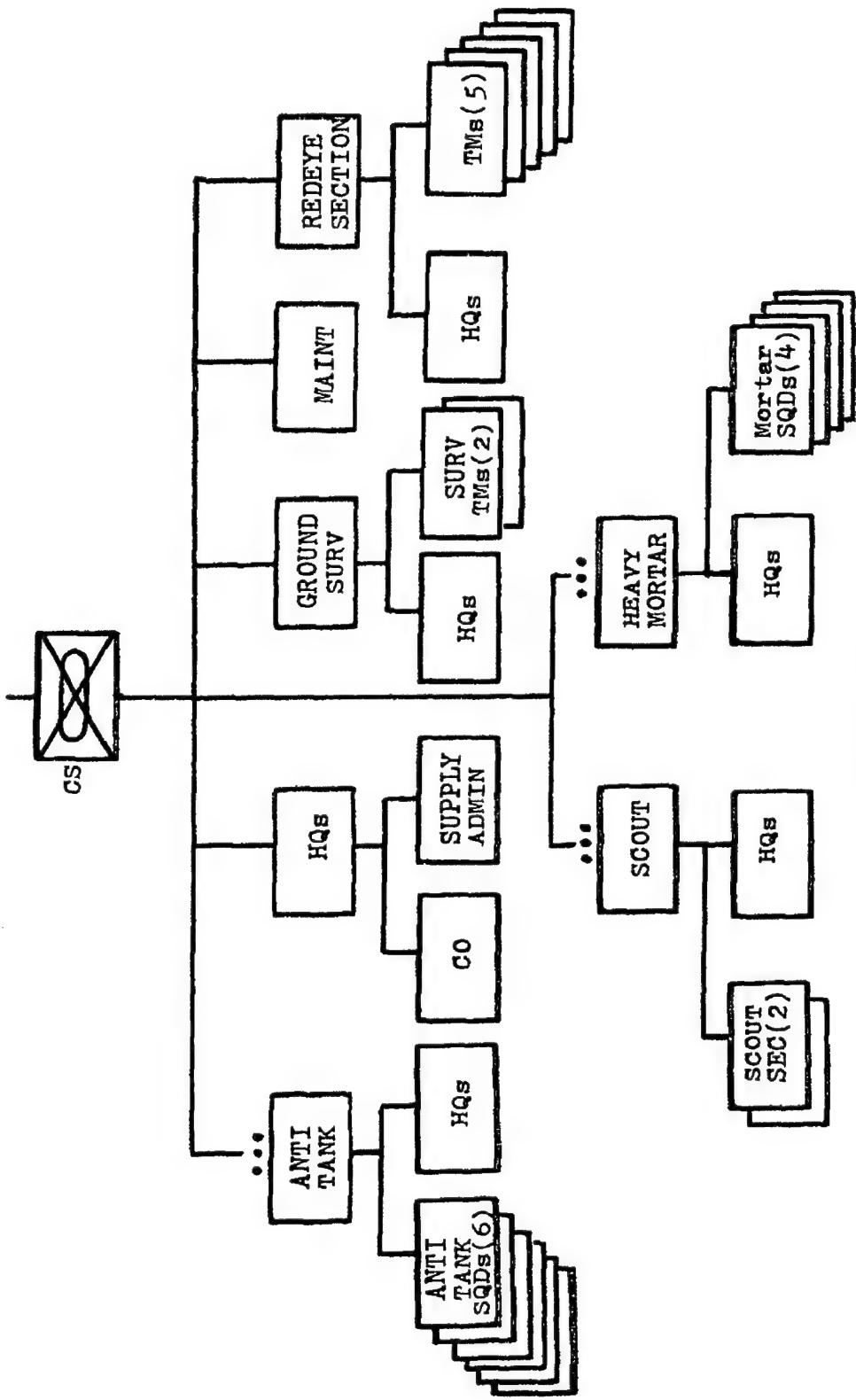
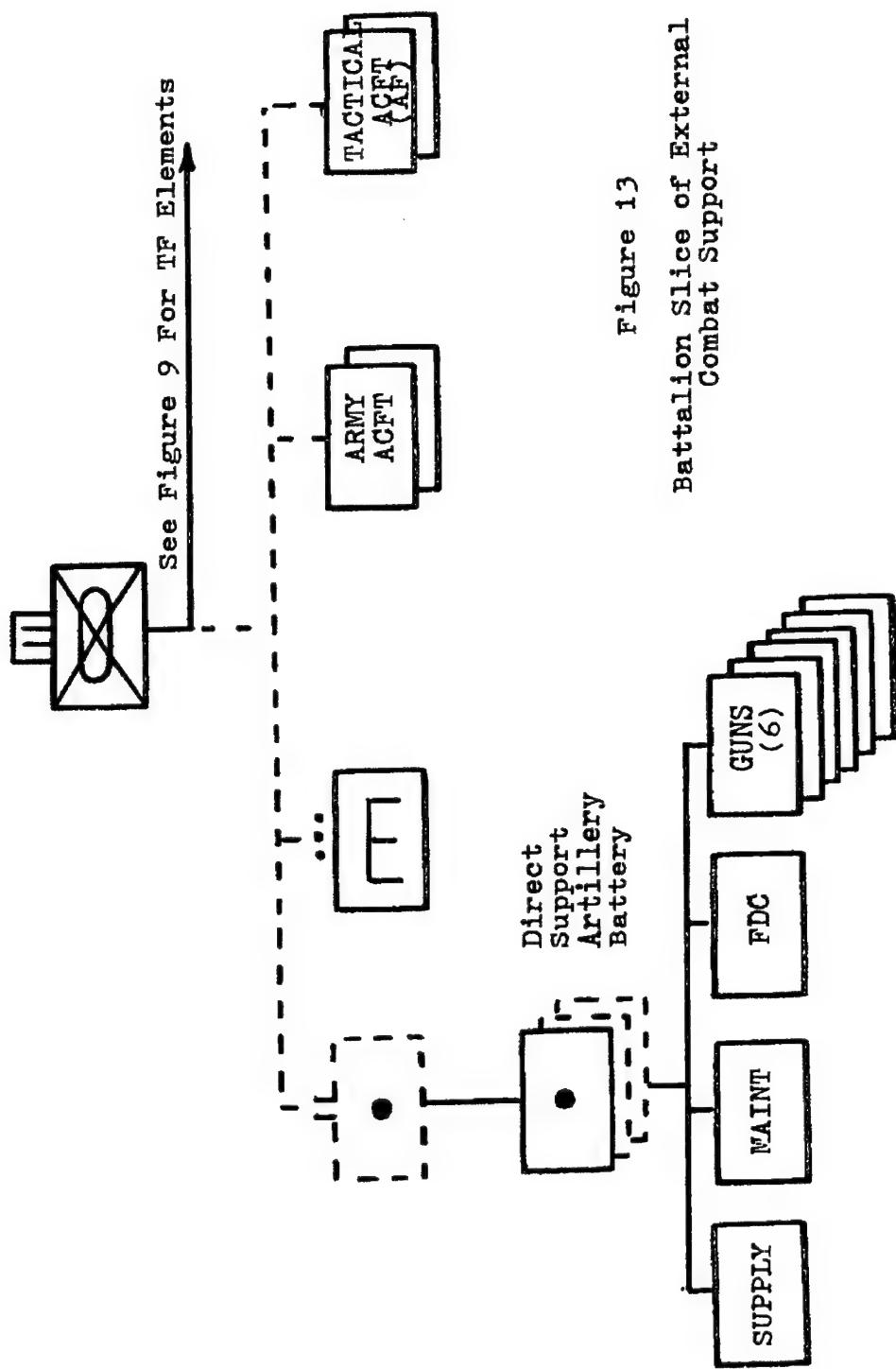


Figure 12  
Combat Support Company Organization

motivating factors have taken the form of a desire to reduce the number of vehicles at company and battalion level and the relative increased effectiveness of supporting artillery and air support systems. The importance of a decision of this nature can be attested to by any Infantry unit commander. The complexity and difference of opinion associated with such a decision is quite significant. A variety of potential organizations could be postulated however, the explicit assessment of effectiveness of each of these organizations requires the combined arms model. A problem of this nature requires the reasonable approximation of the interactive aspects of communications, tactical air, Army Aviation support, artillery, maintenance, supply, etc.

#### External Support Elements

In the preceding example, reference was made to support elements not normally found organic to a battalion. Figure 13 presents four organizations that normally provide support as parts of larger organizations external to the battalion. The units listed are selected as a representative of the "battalion slice" of external support. The artillery organization shown is one battery out of the battalion normally placed in direct support of each committed brigade. In addition to the guns, the maintenance, supply, and fire direction center operations are projected for explicit modeling to insure the capability of



comparative analysis as described in the mortar example. It is anticipated that a platoon level of resolution for the engineer supporting element is adequate. The aviation supporting elements, to include Army Aviation and Air Force tactical support aircraft shown in Figure 13, reflect two aircraft each. Each aerial platform with a wide selection of armaments capabilities and sophisticated control systems should be treated individually and are therefore selected as elements.

#### Task Force Staff Elements

The battalion organization provides the commander a staff which operates in the areas of personnel, intelligence, operations and logistics. These staff officers are traditionally designated as the S-1 through S-4 respectively and are supervised by the battalion executive officer. Each of these staff officers has a significant effect on the battalion's operations and should be designated an element and modeled explicitly. In addition to the organic staff, two other elements habitually operate within the framework of the battalion. The Tactical Air Control Party (TACP) is attached to the battalion by the Air Force to facilitate requesting and controlling tactical air support. The second external staff equivalent element is the liaison team from the direct support Artillery battalion. This liaison element provides critical coordination and assists the commander and his staff in

effectively planning for and employing all supporting artillery fire. Figure 14 portrays these elements.

#### Headquarters and Headquarters Company

The last major element of the task force shown in Figure 9 is the headquarters and headquarters company. The headquarters and headquarters company of the mechanized Infantry battalion is organized as shown in Figure 15.<sup>7</sup> The elements of concern within this organization are those that directly affect the effectiveness of the battalion combat elements.

The battalion communications, support, maintenance and medical platoons meet this criterion. The battalion support platoon requires the treatment of its four component elements; headquarters, transportation, supply and mess sections. The battalion medical platoon must be modeled at the aid station and evacuation section level if the medical evacuation process is to be assessed.

#### Aggregate Requirements

This concludes the analysis of the intentionally complex task force and results in the required resolution by major organization as listed in Table 1.

The total of 139 elements should immediately cause concern, tempered with recognition that this number per-

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<sup>7</sup>Op. cit., FM 7-20, pp. B1-B2.

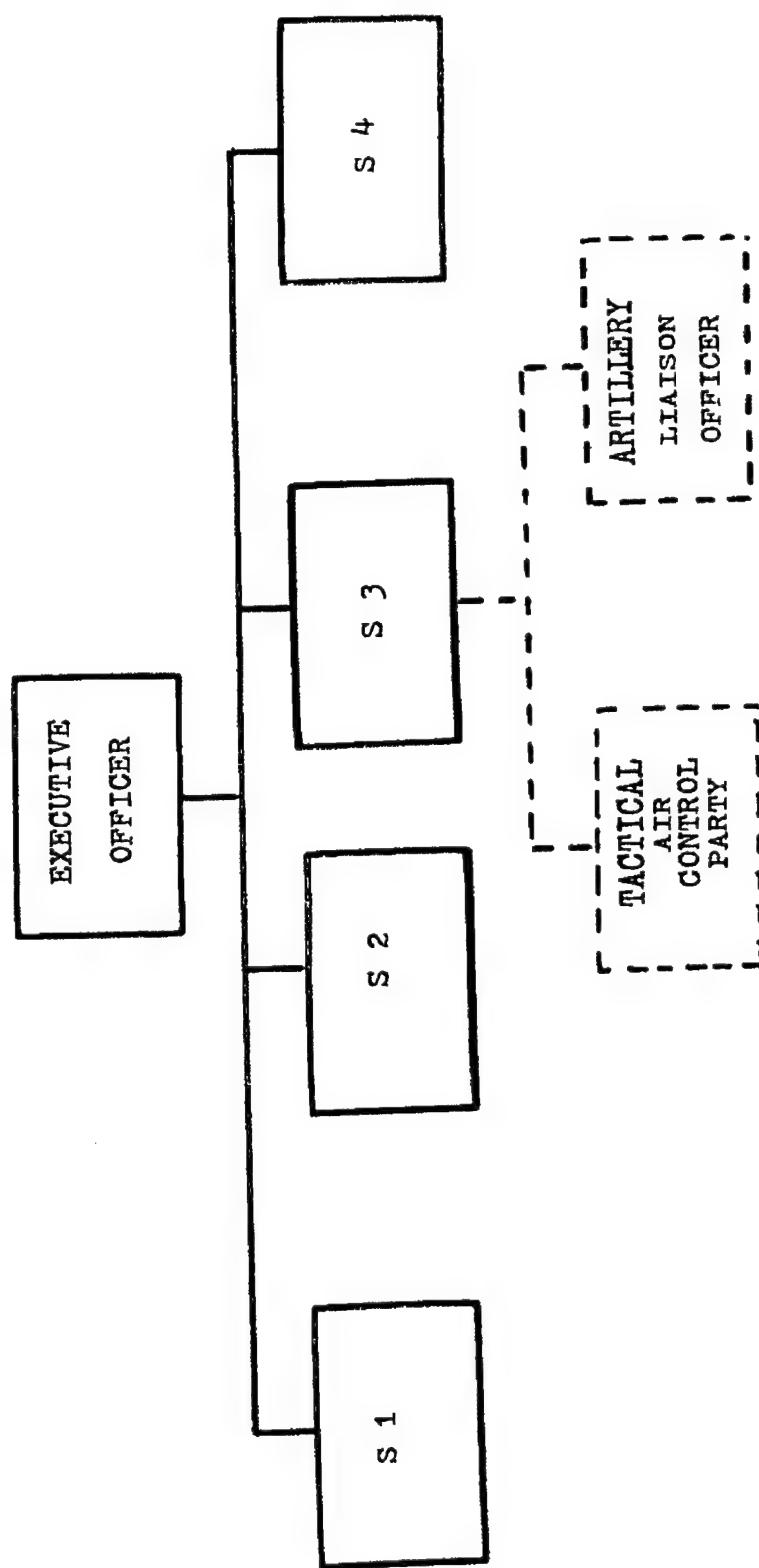
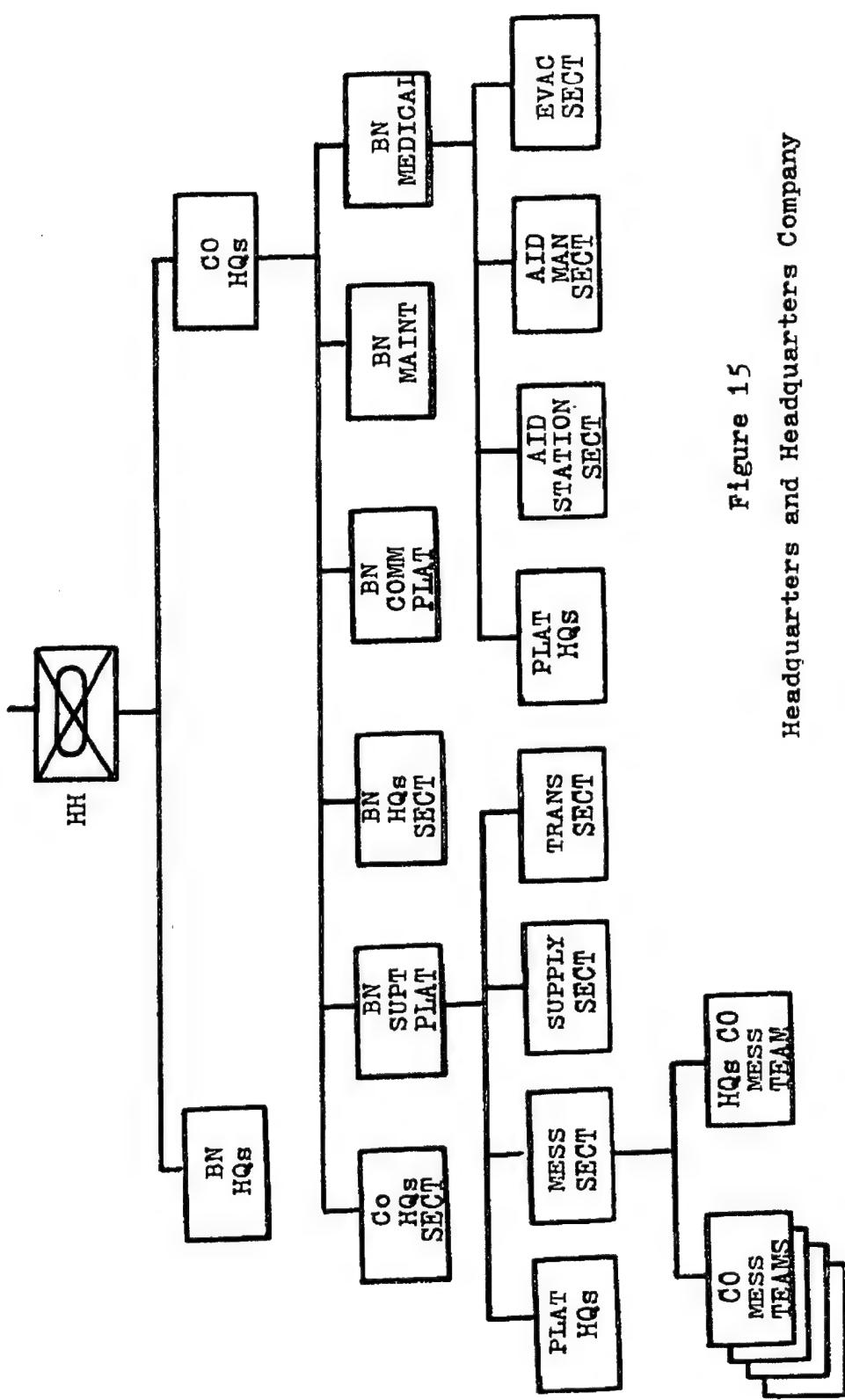


Figure 14

The Battalion Staff Elements



**Figure 15**  
Headquarters and Headquarters Company

Table 1  
Required Levels of Resolution

Organizations	Number of Elements
Mechanized Infantry Team (2)	58
Armor Team	24
Combat Support Company	27
Battalion Slice of Support	14
Task Force Staff	7
Headquarters and Headquarters Co.	8
Task Force Commander	<u>1</u>
Total Elements of Type Task Force	139

mits high resolution to the squad/tank/crew served weapon/aerial platform/staff section/supporting element level. This total further reflects only the blue force of interest and makes no provision for introduction of the opposing forces. It should be assumed that situations presenting the subject task force in a defensive role against an attacking red force would be required. Reasonable expectations of ratios in the order of two and three to one in favor of the red force is appropriate. Due to organizational peculiarities of aggressor forces as well as to aggregate aspects of external support elements, a capacity to treat up to 250 elements should be adequate in satis-

fying these requirements.

## CONTROL

Although many activities take place simultaneously on the battlefield the computer can only approximate this phenomenon since it is restricted to treating one event at a time. The problem of selecting what activity or event is to be undertaken by what element(s) at what time is most readily resolved in the executive routine. The two commonly accepted techniques of control are discussed below with a third preferred method presented for use in the combined arms model.

### Event Sequence Control

In this form of control each element in the simulation has a unique time associated with it. Figure 16 portrays the event sequence method of control. At the beginning of the simulation the elements are normally assigned some weighted random time for purposes of starting the execution.<sup>8</sup> In Figure 16 the starting times for each of the elements are shown by the subscript zero. Once the starting times have been established, the computer searches for and selects for processing the element with the smallest clock time. In the case shown the ele-

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<sup>8</sup>U.S. Army, Combat Developments Command. ASARS Battle Model. Systems Analysis Group. TR 9-73, (Fort Belvoir, Virginia: 1973) Vol. II A, p. II-A-1.

ELEMENT

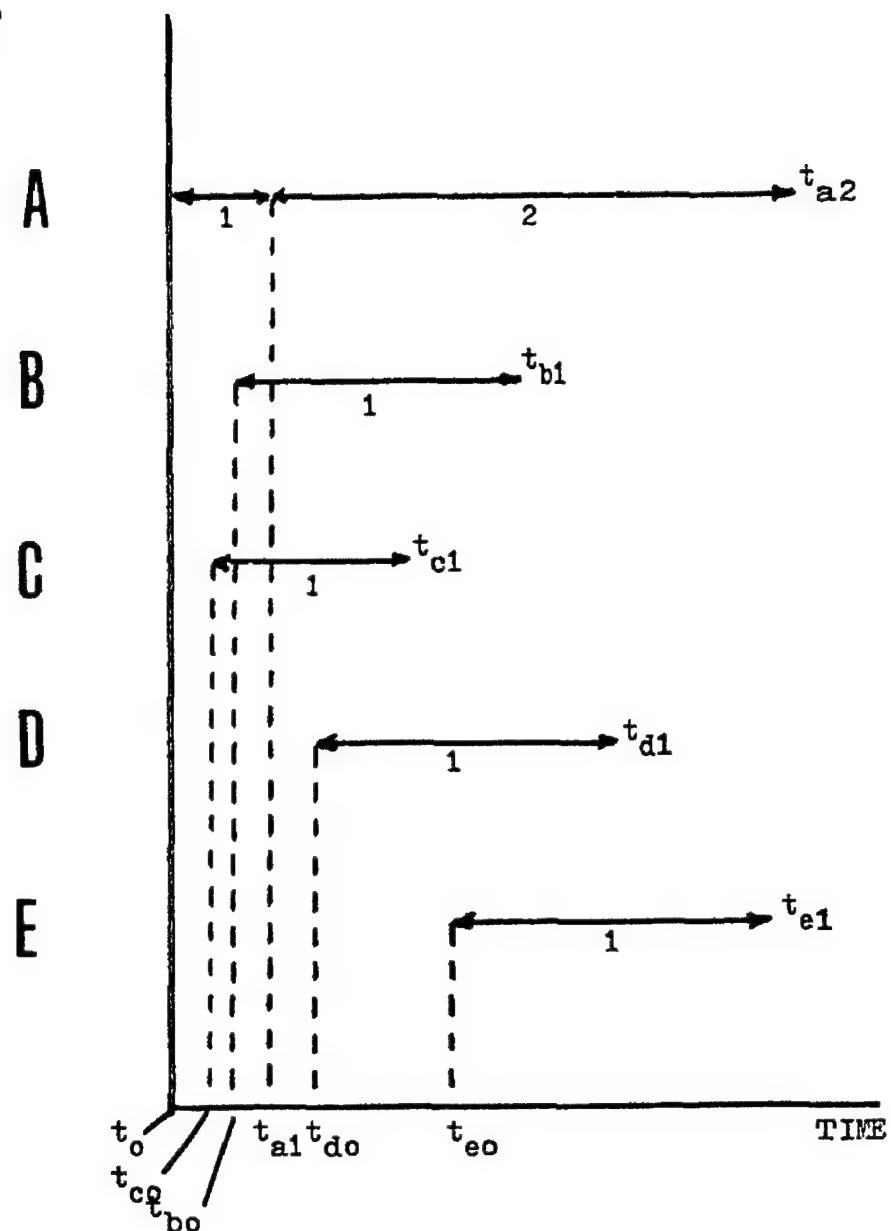


Figure 16  
Event Sequence Control

ment A would be selected. The logic of the model will dictate an event or activity to be undertaken by element A and complete the processing of this element. With this type of control an input is required which specifies the time length associated with every event an element could undertake. The element A would be assigned this time for activity 1 and A's individual clock time is advanced to time  $t_{al}$ . When processing of element A has been completed, control will return to the executive routine and the selection process would be repeated. In the case shown, element C would be selected and processed. This technique is used for control in the DYNTACS and ASARS programs.<sup>9</sup>

Strengths. It is generally accepted that this form of control normally saves running time. If the number of possible events can be constrained, and times for their accomplishment satisfactorily assigned, the program for control can easily be developed. This method provides the easiest approach toward approximating the simultaneous occurrence of events within the constraints of the computer.

Weaknesses. The greatest drawback of this system

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<sup>9</sup>Albert B. Bishop and Gordon M. Clark. The Tank Weapon System. Systems Research Group, The Ohio State University. (Columbus, Ohio: 1969), vol. 4, p. 20.

for control is in the area of accuracy of representation and is therefore most damning. In the event sequence method of control the element with the lowest clock time is selected and then permitted to undertake accomplishment of its activity irrespective of the activity of any other element on the battlefield. Figure 17 presents a situation that could develop. Since  $t_{al}$  was less than  $t_{b2}$ , element A was selected for processing of a communications event of length  $t_{a2} - t_{al}$ . After element A was processed and its message passed, control was returned to the executive routine where element B was selected to complete a firing event of length  $t_{b2} - t_{bl}$ . It can be seen from Figure 17 that element B would complete his firing event before element A had completed his communications event since  $t_{b2}$  is less than  $t_{a2}$ . If element B were firing at, hit and killed element A the communications act undertaken and completed at time  $t_{a2}$  by element A would none the less be considered completed by the computer as a function of sequence alone. Essentially we would have a situation where a dead man (element A) completed an activity that could have a significant outcome on the battle.

Several different approaches toward reducing the occurrence or impact of such a situation have been attempted. Most of them have centered on reducing the time length permitted for events by segmenting the events. A

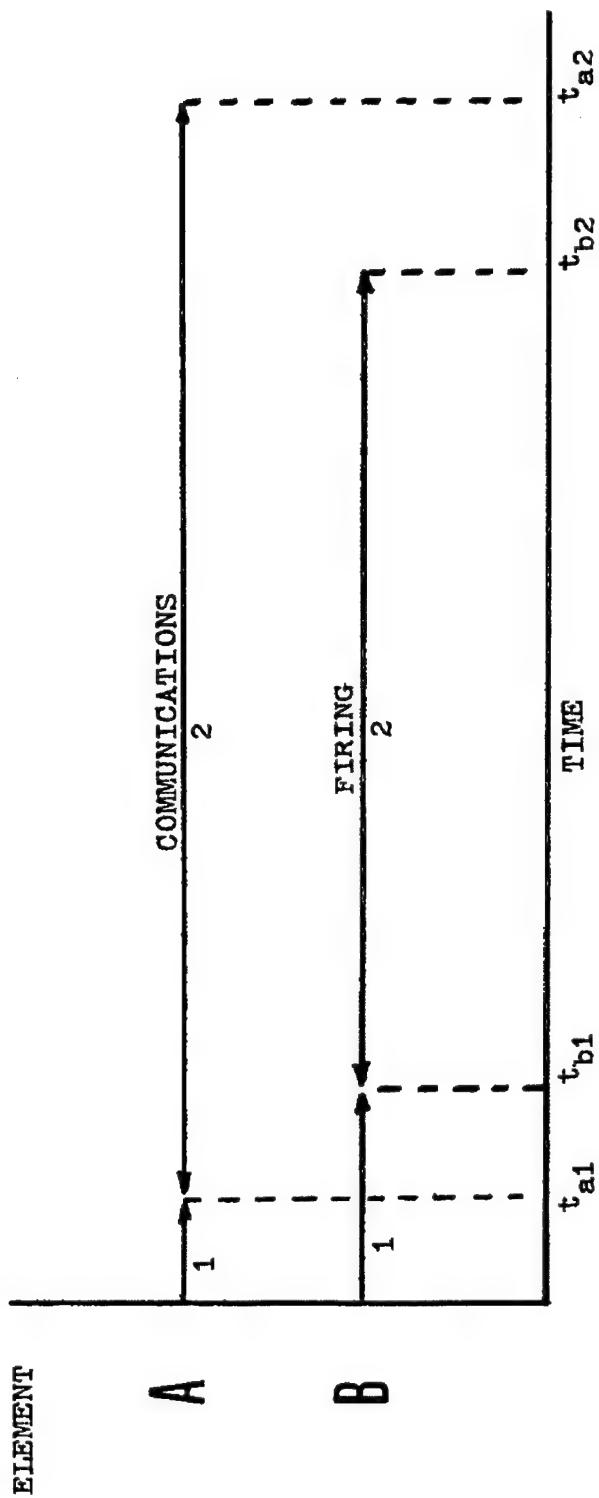


Figure 17  
Event Sequence Weakness

second method has attempted to identify situations as described and then correct any resultant erroneous information. In all cases the result has been to increase the complexity and running time of the programs which has significantly reduced the strengths of the system.

#### Time Sequence Control

In this form of control only a single time exists in the simulation. The executive routine searches through all the elements and their projected activities associating time with these activities. The executive routine selects the event (to be distinguished from the individual) with the shortest projected time and defines this time as the event time. All elements are permitted to progress in their activities toward completion for this event time length. Interactions are resolved and necessary bookkeeping is accomplished before control is returned to the executive routine for definition of the next event. This process is presented in Figure 18. The SIAF program uses a modified version of this time sequence of control.<sup>10</sup>

Strengths. This system of control can best be described by use of Figure 18. Time increments can be forced to be small enough to insure resolution of inter-

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<sup>10</sup>TRW Systems Group. User's Manual Volume I (Redondo Beach, California: 1971), p. 2-60.

ELEMENT

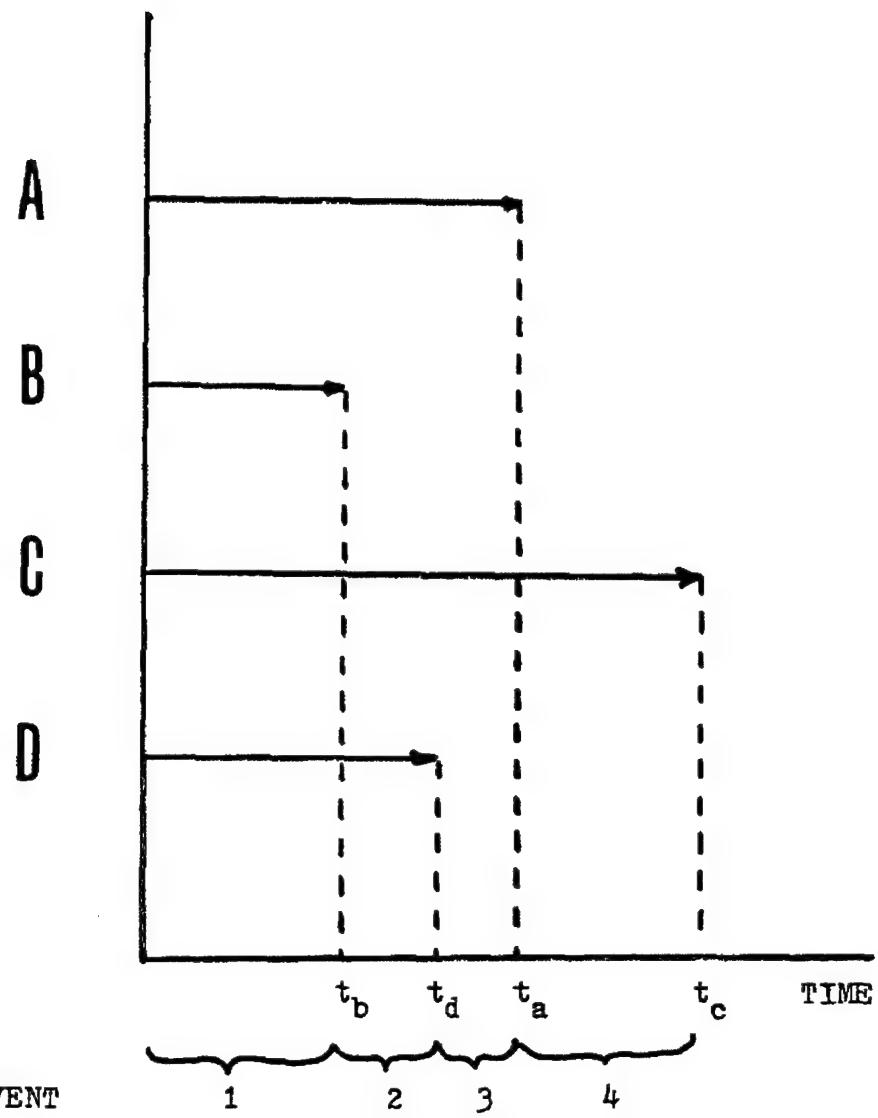


Figure 18

Time Sequence Control

actions before errors are introduced into the system.

Weaknesses. The major weaknesses of this form of control are complexity and running time. The resolution of interactions within an event can readily be appreciated. Emphasis of the major strength of this system favors short event times. This short event time results in frequent "trips" through all the model elements and rapid increase in overall running times.

The Preferred Method  
of Control

The preferred method of control attempts to capitalize on the strengths of each of the two preceding methods while minimizing their weaknesses. An optimal system would use the event sequence when no interaction takes place but shift to the time sequence method when interactions frequent the simulation. Attempting to revise the program for control in the midst of an execution would be complex and consuming in terms of both computer storage and running time.

The requirements with respect to the control methods can best be understood by taking the hypothetical task force specified earlier in this chapter and carrying it through a form of attack. Initially, as the simulation begins, the elements will primarily be maneuvering in accordance with some prescribed plan. The opposing forces on the battlefield will have only initial informa-

tion about their opponent. The attacking elements will be principally concerned with movements while the defenders primary interest will be surveillance of the battlefield. This segment, which will be called Phase 1, is characterized by the absence of exchange of fire by the forces and thus no damaging interaction. In this phase the optimal method of control is event sequence with a long permissible time length for each event.

The second phase is introduced by the first exchange of fire by the combatants. These exchanges are characterized by long range engagements and interactions involving a relatively small number of elements. In this phase, event sequence, with a time restriction more limiting than that of Phase 1, is required.

The third and final phase is initiated when the opposing forces close to some preselected distance within which it can be forecast that significant interaction will take place. The preferred method of control here is an event sequence that will be radically constrained in permitted time length of each event. This last constraint will cause the event sequence control method to approximate the time sequence control method.

This proposed method of control, to be entitled, Event Sequence Time Constrained, will function as shown in Figure 19. The program activities are shown to initiate at time  $t_0$  by the selection of element A to engage

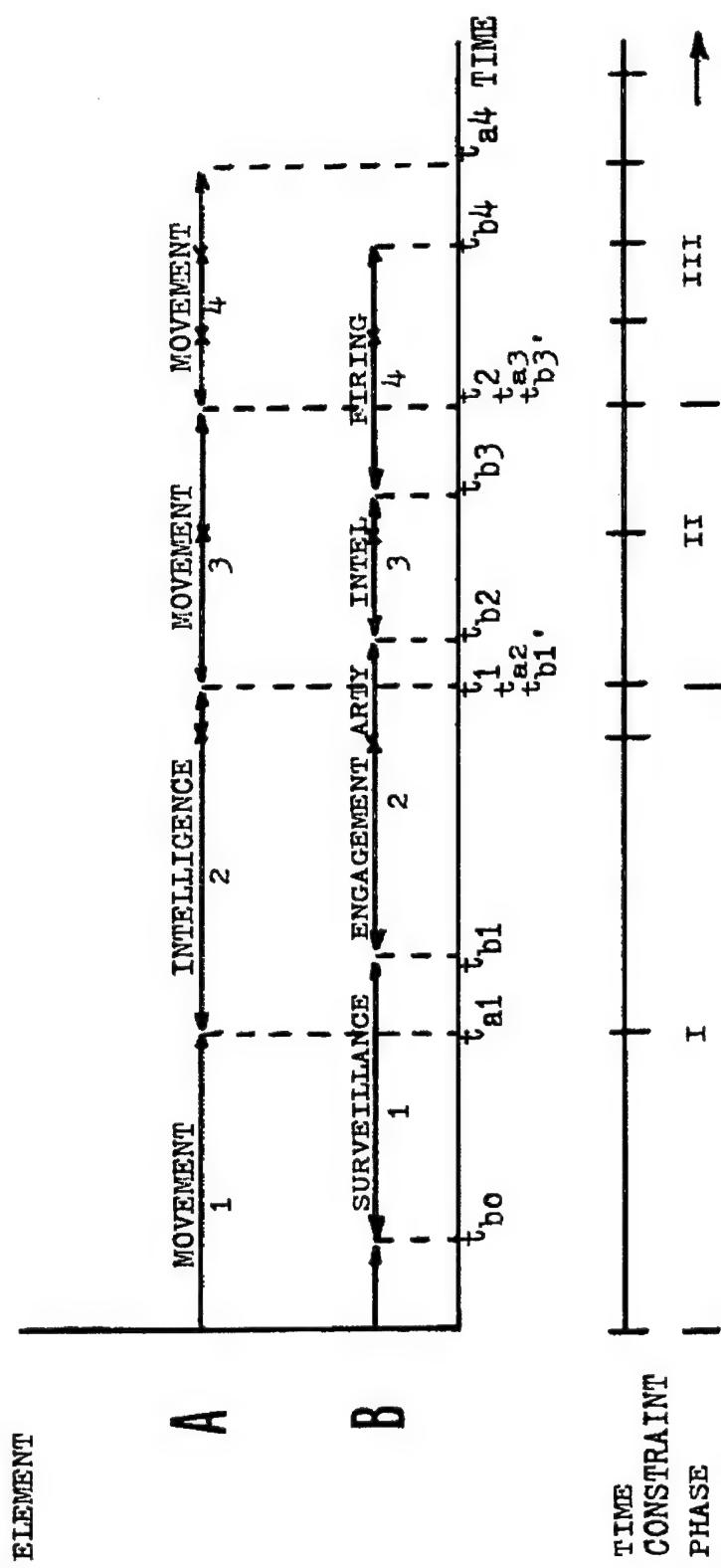


Figure 19  
Event Sequence Time Constrained

in a movement activity shown as activity  $A_1$ . This activity requires time length  $t_{al}$  to complete and will complete this event within the maximum allowable event length specified for Phase 1. Element B has been engaged in battlefield surveillance and has terminated activity at  $t_{bl}$  due to the acquisition of element A. It is assumed that element B has elected to engage element A with artillery fire and delivers these fires in sequence  $B_2$ . The intelligence event  $A_2$  has been terminated by A's recognition that he was effectively engaged. Control returns to the executive routine where the program control is advanced to Phase 2 where the maximum permissible time length of an event is constrained to that assigned for Phase 2.

The situation presented in Figure 19 depicts A's selection of a movement option. It is assumed that this movement event, which was interrupted due to the Phase 2 constraint, causes element A to close to the input threshold separation distance. Control is returned to the executive routine. The executive routine will now step the simulation to the final phase, Phase 3, where events will be radically constrained in their permitted duration. Once entered, each higher phase cannot be regressed until the program is reinitialized.

The technique of control described as event sequenced time constrained was attempted in the ASARS Battle Model program. Due to reorganization of the Army in 1973

work in this area had to be terminated in the interest of completing the program before dissolution of Systems Analysis Group.

#### ANATOMY OF A MODEL

Earlier chapters of this thesis have critically evaluated existing programs while earlier portions of this chapter have described desired resolution and a scheme for control of the combined arms model. Prior to initiating the developmental effort, for this model, it would be helpful to analyze in some detail a program that closely parallels the desired combined arms model. The vehicle for this discussion will be the ASARS Battle Model which was evaluated in the preceding chapter. This analysis will discuss the logical grouping of subroutines and functions within the model and will also serve to demonstrate the potential use and consequent need for specific items and forms of documentation.

#### Execution Logic

Figure 8, ASARS Battle Model Execution Logic, in Chapter III presented the execution logic for the ASARS Battle Model. This figure describes the sequence of activities and interrelationships that have been programmed. Seven major subprogram groupings subordinate to the executive routine, FOLOME, can be described. These seven major subprograms model at least portions of four

of the five functions with which we are concerned in the following pattern:

Intelligence	-	INTEL
Firepower	-	FCONTR
	-	FIRMOD
	-	CASA
Mobility	-	MCONTR
	-	MOVMOD
Command, Control and Communications	-	COMMUNE

The sequence in which these subprograms are entered is not arbitrary. The Intelligence function within any event should logically be expected to present information which will influence the other functions and therefore has been positioned early in the program. Similarly, casualty assessment, possibly resulting in force adjustment, should be near the end of the sequence to permit the proper assessment and adjustment of forces as required by some preceding actions. To accomplish this the casualty assessment (CASA) and communications (update of information COMMUNE) subprograms have been positioned in the later portions of the executive routine. Although control and access to these subprograms can be controlled through programming techniques the logical arrangement of these subprograms will facilitate the programming effort and will become critical if overlaying techniques must be

applied due to constraints of computer storage capacity. A pictorial presentation of the logic, like Figure 8, assists the analyst in tracking the logic of the program and facilitates understanding of the program by the user.

#### Subroutine Mapping

General. Although the execution logic diagram is useful to both the analyst and the user, additional information about the execution of the program can be gained by reformatting the same information. This reformatting will describe the interaction of subroutines from lower to higher levels as opposed to the overall presentation shown in Figure 8. Figure 20 presents in matrix form the mapping of the subroutines from lower to higher levels as opposed to the overall presentation shown in Figure 8. Subroutines 70 through 72, which deal exclusively with measures of effectiveness, have not been included within the body of the matrix.

The numbers in the extreme right hand column reflect the number of subroutines listed across the column headings that called the subroutines listed as row headings along the left. The numbers along the bottom of the columns help to identify the calling hierarchy of the subroutines listed at the column heading. Those with zero entries indicate that the subroutine is basic, defined as one which completes an operation without calling on another subroutine. Insight into the degree of dependence

## Figure 20

### Subroutine Mapping

on other subroutines can be gained by examination of the numbers at the bottom of the columns. An extract of those subroutines called by two or more other subroutines is presented in Table 2.

Figure 8 has served to illustrate the logical organization of the executive routine by concentration on the major functional areas simulated. Figure 20 and Table 2 more specifically identify subroutines which accomplish this modeling and, most important, identify those type subroutines which support more than one function. Those subroutines supporting more than one functional area describe a grouping which provide general service to the model. These service routines can be grouped into treatment of terrain and communication. The importance of terrain comes as no surprise, however, communications warrants further investigation.

Analysis of communications indicates that its introduction as a service group is based upon its transfer and storage of situational type information. The hierarchy and interrelationship of elements in the ASARS Battle Model is recorded in the communications peculiar subroutines. This would indicate that the second service grouping should be properly identified as a status of elements group as opposed to restriction to communications alone. This suggests that information on the operational environment and status of elements within the simulation

Table 2

## Subroutine Mapping - ASARS II Battle Model

Subroutine	Calls	Called By	Functional Area
COMMEX	0	COMMEL COMUNE FCONTR IDETT IFRAW IMPUGN IPLAT IPORT IRAD ISOPOD ISQUID ITASCA IXION	C, I & F
COVINT	0	CASA FIRMOD	C, F
COMMEL	COMMEX	FOLOME ERF FCONTR	F
	ERF	VILOS XLOS RANDOM	
DESEP	0	INTERP RETRO	X
ERF	0	COMUNE FIRMOD FPICK IPORT	C, I, F
FCTGTU	0	BATSUM FCONTR	F
FIRMOV	0	MCATT MCMINE	X
PTRAJX	0	FIRMOD FPICK	F
IDIOT	0	IMPUGN ISOPOD IXION	C
INTERP	DESEP RTTIVE WLDR	ASSESS MOVMOD	X, F

Table 2 (continued)

Subroutine	Calls	Called By	Functional Area
ISIT	0	FCONTR MCATT	F,M
ISCPOD	COMPLEX TDIOT	IFRAM IPLAT ISQUID	I
ITASCA	COMPLEX	IFRAM ISQUID	I
IXION	COMPLEX TDIOT	IPLAT ISQUID	C
MCBACK	MCDEF MCWIN MCRTSL MUNIN	MCONTR MCOP	M
MCDEF	MCRTSL MUNIN	MCBACK MCONTR MCOP	M
MCHECK	0	MCATT RETRO	M
MCFORM	MUNIN	MCATT MCWIN MCOP	M
MCWIN	0	MCBACK MCOP	M
MCRTSL	ASHARD MCTF RTTIME VLOS XLOS ZUP	MCATT MCBACK MCDEF MCOP	M
MCTF	0	ATIME IDETT MCNINE MCRTSL MOVMOD RHW RTTIME	I,M

Table 2 (continued)

Subroutine	Calls	Called By	Functional Area
MUNTN	0	FCONTR MCATT MCBACK MCDEF MCFORM	F,M
PLADEP	0	MOVMOD RTTIME XLOS	M
RANDU	0	ASSESS FIRMOD IRAD	I,F
RTTIME	MCTF PLADEP ZUP	ASHARD INTERP MCRTSL WLDR	M
VLOS	ITEST ZUP RANDOM	COMUNE IDETEK IDETT IRAD ISQUAD MCRTSL MOVMOD	I,C,M
XLOS	PLADEP ZUP	COMUNE FCONTR FIRMOD FPICK IDETEK IDETT IRAD ISQUAD MCRTSL MOVMOD	C,F,M,I
ZUP	0	AFLTIM ASSESS ATIME FIRMOD FPICK MCRTSL MOVMOD RTTIME VLOS XLOS	F,"

Table 2 (continued)

Subroutine	Calls	Called By	Functional Area
RANDOM	0	ARTY ASSESS CASA COMUNE FIRMOD GETIT IDETEK IDETT IPORT IRAD MOVMOD NROUND RW SELECA VLOS	F,C,M,I,SS

## Functional Area Code:

F = Firepower

M = Mobility

I = Intelligence

C = Command, Control and Communications

SS = Combat Service Support

should be controlled centrally in the executive routine.

#### Variable Control

Prior to actually building the combined arms model executive routine the generation and use of specific variables within a simulation must be understood. Again using the ASARS Battle Model as a vehicle for discussion one can realize constraints on model development which should be applied in the development of any large scale computer simulation.

The variables are the mechanism by which the computer transfers information. In the ASARS Battle Model there are 472 common variables which are either input to describe the desired initial situation or are generated internally for initiation of the program. These variables are then applied in the various subroutines to simulate the action desired. A mapping of these commons by subroutines is shown in Appendix A. The type of mapping reflected in Appendix A enables the user to evaluate the use of each variable in each subroutine and better understand the true meaning of each numerical value.

To facilitate such an evaluation additional information should be retained for each variable. Figure 21 is an information sheet developed for one of the 472 variables in the ASARS Battle Model. This information sheet is the end of the chain beginning with the Model Execution Logic of Figure 8, through the subroutine and common

PAGE 1 of 2 PAGES

DATA INPUT WORK SHEETNCLOCK  
NAME

1. DEFINITION: Element number of element who INTEGER/REAL just completed sending a message

1A. RANGE: \_\_\_\_\_ > NCLOCK < DIMENSION: ( 30 )

2. SOURCE OF DATA: JUDGMENT (J) OR/AND SPECIFIC (S) S

3. APPLICATION: WHERE: HOW: Sets current element number into net position (NT) of NCLOCK to indicate a message has been trans.

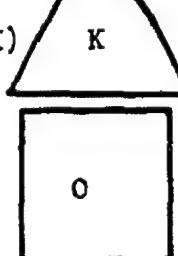
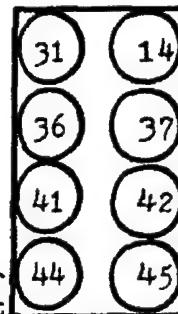
COMUNE IFRAM Fire Team logic which checks if he gain info this event.

IMPUGM IMPUGM Performs data trans for plat on company net. Set net ID and resets flag.

4. DEMONSTRATED SENSITIVITY: YES NO

5. TYPE CLASSIFICATION: CONSTANT (K)/SCENARIO(I)

- A. TACTICS & DOCTRINE (T)
- B. SCENARIO (S)
- C. WEAPON SYSTEM CHARACTERISTIC (W)
- D. OTHER SYSTEM CHARACTERISTIC (C)
- E. OTHER: initialize



6. RUN IDENTIFIER: \_\_\_\_\_

7. DATA:

NCLOCK (NT), NT = 1,30 = 0

Initialize to zero

-----  
Item 3 Continued:

ISOPOD: Performs data transfer for the maneuver unit net. Sets index and then zeros flag.

ISQUD: Determines if an intelligence message has been completed on a net that the squad ldr has access to. Sets appropriate flags for transfer.

ITASCA: Perform Figure 21 in squadnet.  
Sets inc

IXION: Perform Data Input Work Sheet in squadnet on resets  
the plat flag.

Item 3 Continued:

IPLAT: Check if message sent by platoon leader has been completed & calling appropriate routine to transfer info. Sets flag for transfer of info in platoon.

REMARKS: This common is set to the element number communicating on the net NT when the communications has been completed. This setting is accomplished by the COMUNE subroutine. The hierarchy of operation is described in the following diagram.

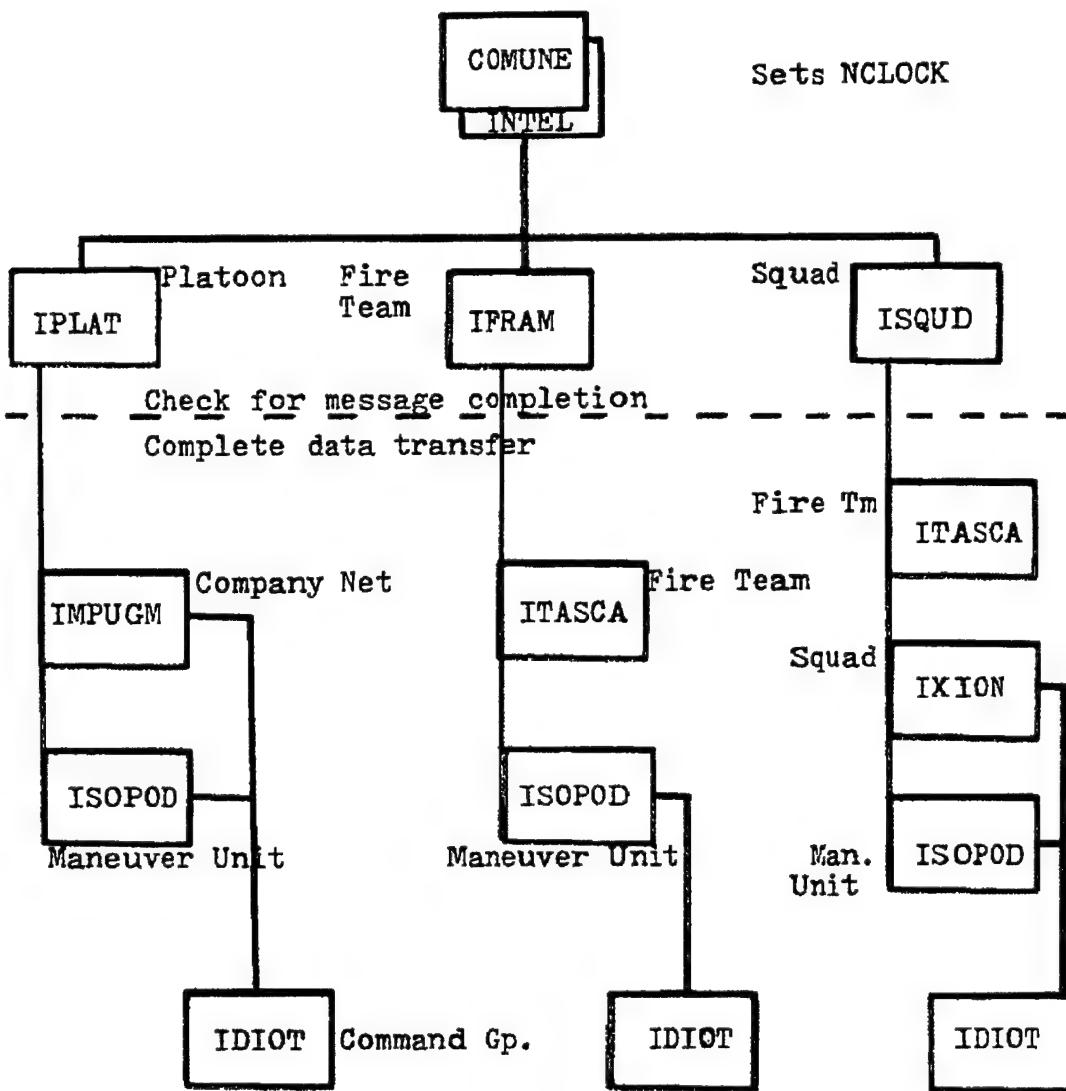


Figure 21 (continued)

mappings of Figure 20 and Appendix A respectively and concluding with the information sheet in Figure 21.

#### PHASE A EXPANSION

As described earlier, this phase of the executive routine development is the first step in the description of the overall system to be simulated. Applying the guidance of the earlier portions of this chapter the following functions must be controlled by the executive routine:

Environmental description

Status of elements

Control

Intelligence

Mobility

Firepower

Command, Control and Communications

Combat Service Support

To complete the Phase A development it will be necessary to order these functions. To accomplish this ordering the task force organization developed earlier will be wargamed in a general sense.

#### Hierarchy of Functions

Control. Control is an administrative function accomplished by the executive routine. This function will

select the next element to be processed in a manner described in the second major section of this chapter. It must be accomplished early in the execution cycle to permit subsequent subroutines to focus their attention on specific elements. The control function should be first in the required hierarchy.

Environmental description and Status of Element.

All actions subsequently addressed in the processing of an element will be based on one "frame" of a "motion picture" of this activity. The purpose of the environmental and status aspects of the executive routine is to present the situation, by element, for use by the remaining functional areas of the program. Since the information is required for application by the following combat function areas it must precede them but must follow the control area as a specific element must have been selected for processing.

Intelligence. The first of the combat functions that should be addressed is Intelligence. Decisions and actions are made and undertaken based upon information developed during the intelligence gathering function. The intelligence function is that in which most elements expend at least some effort most of the time even if it is limited to simple undirected observation. Due to its heavy use and since it provides information to support

the other functions it should be next in the hierarchy of functions.

Command, Control and Communications. Based upon all prior information decisions will be made at all levels of command/control within the task force of interest. These decisions would control application of firepower, movement and provision of combat service support. It is expected that this process should follow those providing information needed by it but preceding those functional areas depending upon decisions rendered by this function. These considerations place command, control and communications next in the hierarchy.

Mobility and Firepower. These are virtually mutually exclusive events. Except for special identifiable circumstances both of these functions would not be undertaken simultaneously. Their relative order for purposes of application in the executive routine are interchangeable but will be set as mobility and firepower in that order.

Combat Service Support. The major input in this functional area would be the implementation of activities previously described or the restriction of these activities due to constraints of the system. This function will largely be that of bookkeeping and trade off within capa-

bilities and will require results of earlier activities to properly accomplish its function. Due to this dependence it should be last in the hierarchy of functions.

Resume. Based upon the preceding discussions the hierarchy of functions within the executive routine is established as follows:

Control

Environmental description

Status of elements

Intelligence

Command, Control and Communications

Mobility

Firepower

Combat Service Support

#### Executive Resolution

Within each of the eight major executive routine functional areas a different degree of detail will be required dependent upon the individual element being processed. The control, environment and status functions will be required on each individual element for each cycle. In the case of the remaining functional areas however, different degrees of executive resolution will be required dependent upon the level of command within the task force of interest. Economies in operation could be realized if the "current element" is routed through only that logic

necessary to accomplish its purpose. This suggests that the detailed logic developed for each of the five combat functions be layered in such a manner as to facilitate processing elements of varying levels of command within the task force. To this end a master functional area controller for each combat functional area should be developed which will control accesses to portions of a more detailed execution program. This suggests that in each combat function area there would be a relationship similar to the following example of the intelligence function:

Intelligence Controller

Intelligence Routine

The pictorial presentation of the Phase A expansion thus far concluded is presented in Figure 22.

#### PHASE B EXPANSION

This phase of the executive routine development uses the phase A expansion (Figure 22) as a point of departure and introduces the tactical detail necessary for reasonable control and execution. The following discussion will methodically expand each of the eight major executive functions.

##### Control

There is little need for expansion of this execu-

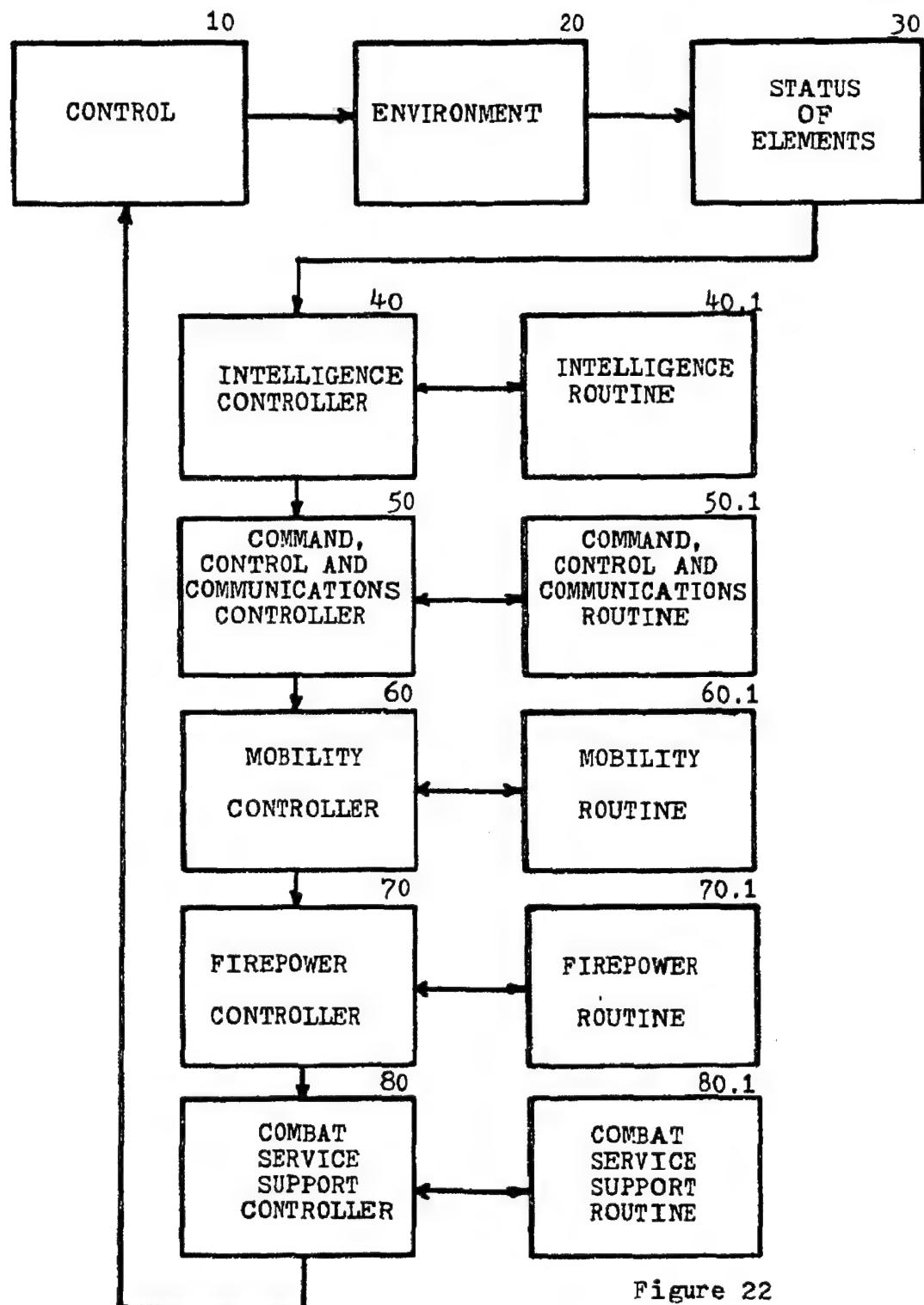


Figure 22

Phase A Expansion

tive function as it does not include explicit tactical control considerations. Each element will require a variable that will maintain a running record of its time. We can specify it as CLOCK(I) at this point. CLOCK(I) will be a real variable subscripted by (I) to identify a time associated with each element simulated. Based upon earlier discussions of resolutions, space should be reserved at this point in time to accommodate up to 250 elements. An additional time-associated variable, CLOCKA, will be used to maintain a record of the actual simulation elapsed time. A third variable should also be introduced, CLOCKB, which will be the time at which the simulation is to begin. This last variable will permit the introduction of weather and time of day considerations.

#### Environment

In modeling the environment it is necessary that all factors which can affect the application of the functions of land combat be included. The environmental aspects of interest can be categorized as either terrain or weather with the latter category including light conditions.

Terrain. At this point in development it is not appropriate to go into the details of terrain modeling. It is appropriate however, to discuss those applications of terrain that are needed to assist military decision-

making. The method of modeling terrain preferred will be presented in Chapter V.

The location of each element on the battlefield must be known. To explicitly locate each element it's X and Y cartesian coordinates must be known. These variables are real and are designated ELOCX(I) and ELOCY(I). Some portions of the program will also require the Z plane position of the element, however, techniques exist to quickly determine the Z component given X and Y components and valuable storage capacity need not be programmed for storage of the Z coordinate.

The terrain program must be capable of portraying relief and of introducing vegetation into the program for consideration. This use will normally be employed to determine if a portion of the target is obscured by terrain masking (XLOS) or by vegetation masking (VLOS). Facts returned upon inquiry will be whether or not line of sight between two or more elements exist in both XLOS and VLOS and what fraction of each potential target is exposed.

Weather. Weather will impact to increase difficulty in applying each of the combat functions, most importantly in the area of visibility. The program will be required to assess the impact of weather in each functional area. This portion of the environmental program must be capable of introducing the appropriate factors to describe light conditions, trafficability and weapon sys-

tem performance factors resulting from input environmental conditions normally keyed to simulation time (CLOCKA + CLOCKB).

Conclusions. It is not necessary to describe the explicit modeling of the environment at this time. This will be described in Chapter V. For purposes of executive routine development it is sufficient to describe those factors which must be provided by this subprogram to permit meaningful decisions and applications to be undertaken later in the program.

#### Status of Elements

This subprogram is a bookkeeping repository of information which, in addition to the environment, is necessary for decision-making and execution of the subsequent combat functions. Information such as the status of inter-element acquisition (IDETT), status of supplies (SUPLVA, SUPLVB, SUPLVC, SUPLVD) and status of forces (SURV) will be required. Each of these groupings will be discussed below:

Interelement acquisition (IDETT). This will necessarily be a large matrix (250,250) which will reflect a level of knowledge on the part of any one element I of any other element J. The ASARS Battle Model uses levels of acquisition which are considered adequate. The six levels desired for use in the combined arms model are listed below:

- 0 No knowledge.
- 1 Knowledge communicated from external elements.
- 2 Knowledge communicated from organic elements.
- 3 Decreased knowledge from prior 4 or 5 levels.
- 4 General localization and identification.
- 5 Total knowledge to include location and identification through direct observation.

It may be noted that states 1 and 2 reflect "how" while the others relate to "what" of knowledge. This hierarchy is necessary to support internal decision logic which will favor higher states of knowledge.

Status of Supplies (SUPLVA, SUPLVB, SUPLVC, SUPLVD). The A through D modification of the SUPLV (Supply level) prefix are intended to correspond to the I, III, IV and V classes of supplies. If explicit modeling of the medical and maintenance operations are undertaken classes VIII and IX must be added. Within each class of supply the individual element status, reflected as the portion of authorized remaining, will be maintained for the individual element and aggregated in the case of leaders for his subordinate units. This concept is an expansion of that supply constraint employed in the leadership logic of the Fire Controller of the ASARS Battle Model.

Status of Forces (SURV). This information matrix will retain a record of the known composition of own

forces for both sides in the simulation. A percentage of forces remaining within each subordinate element will be recorded. It must be possible to cause erroneous information to be entered in this information matrix to represent failures in communications and cause less than optimal decisions to be selected if appropriate.

#### Intelligence Controller

This is the first of the controller programs to be encountered which control the access to specific routines within each of the five combat function areas. This subprogram will be entered by all elements however, only leaders will perform the detailed functions executed within it. Each individual not a leader will be routed to the appropriate individual intelligence subroutine for processing. Within the intelligence controller, leaders will make decisions with respect to the application of their information gathering assets. Plans for battlefield surveillance will be formulated and instructions for their implementation prepared in this program. Within appropriate subroutines each of the relevant intelligence functions will be implemented. At this point in development the following required routines can be visualized:

Individual Acquisition to include:

Man - Man

Man - Vehicle (air and ground)

Vehicle - Man (air and ground)

Electronic - acquisition

Electronic Surveillance, to include:

EW, Radar, Sensors, etc.

Aerial Surveillance

Aided Visual

Command, Control and Communications Controller

Like the intelligence controller this subprogram will be entered by all elements but nonleaders will quickly be routed to appropriate detailed subprograms. Within this subprogram the functions of the task force staff shown in Figure 14 will be modeled. Staff coordination and planning with appropriate time assessment will be accomplished in this program. Decisions appropriate to a level of command will be formulated at this point and control will pass to the communications routine to affect the required communications. Only upon successful completion of the communication will the appropriate information matrices be changed.

Mobility Controller

This major subprogram will be concerned with leader decision-making with respect to maneuver of forces. The logic controlling dynamic maneuver and route of selection will be contained in this program. Elements not designated either initially or dynamically as leaders will

be routed to a movement model to complete their event.

#### Firepower Controller

All intended application of firepower both organic and external will be controlled through this subprogram. Decisions by leaders with respect to control and distribution of fires will be made within the controller of this program. Detailed execution of the firing to include assessment of effects will be concluded in the detailed firing models subordinate to the controller. As a minimum the following separate firing models will be required:

Direct fire dismounted.

Direct fire mounted.

Indirect fire.

Air to ground.

Ground to air.

A single casualty assessment model would be entered following each engagement to assess the effectiveness of the fires and adjust the status of forces matrices as appropriate.

#### Combat Service Support Controller

The controller portion of the subprogram will be concerned with the development and execution of decisions by appropriate leaders with respect to the distribution of supplies. The detailed models subordinate to the controller will actually effect the resupply at rates appro-

priate to their capabilities. Capabilities will be modeled at the appropriate level for each of the classes of supply of interest.

#### Combat Operations

"In their broadest sense, the terms 'offense' and 'defense' include the entire range of tactical operations."<sup>11</sup> This reference would imply that it is sufficient to model one force as the attacker and the opposing force as the defender. Indeed this is true except for the peculiarities, with respect to computer operations, of the type encounter classified as the meeting engagement. In this type of encounter the critical and confounding factors are the simultaneous maneuver of both forces and the characteristic relatively close range violent exchange of fire. In this situation, for some relatively short period of time, both forces are attacking. After some time interval one force will become an attacker while the other performs some defensive action. Objectives are normally changed from those originally intended and the battle continues. The executive routine must be capable of dynamically assessing the situation and directing a course of action. User intent (to execute a meeting engagement) can be introduced by a flag in the form

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<sup>11</sup>Department of the Army. FM 100-5 Operations of Army Forces in the Field. (September 1968) 9. 6-1

of an integer variable (MEET) being set to 1 to reflect a meeting engagement or 0 for otherwise normal operations.

#### Administrative Control

The executive routine must control the beginning and ending of the operation as well as providing a detailed history of the battle and data for development of measures of effectiveness. The executive routine must contain provisions for storage of the history, providing interim summary data at preselected points of analysis and terminating the simulation, providing a concluding summary at the appropriate time.

#### Conclusions

A pictorial representation of the Phase B expansion to this point is presented in Figure 23. It should be noted that the distinguishing feature of this Phase B expansion is its detailed tactical logic but void of the characteristic FORTRAN IV programming language.

### PHASE C EXPANSION

This last phase of the executive routine expansion bridges the gap between the tactical logic reflected in Figure 23 and the computer programming requirements of FORTRAN IV. This development is necessarily tentative at this point in time because the final program will reflect changes required by the detailed development and integra-

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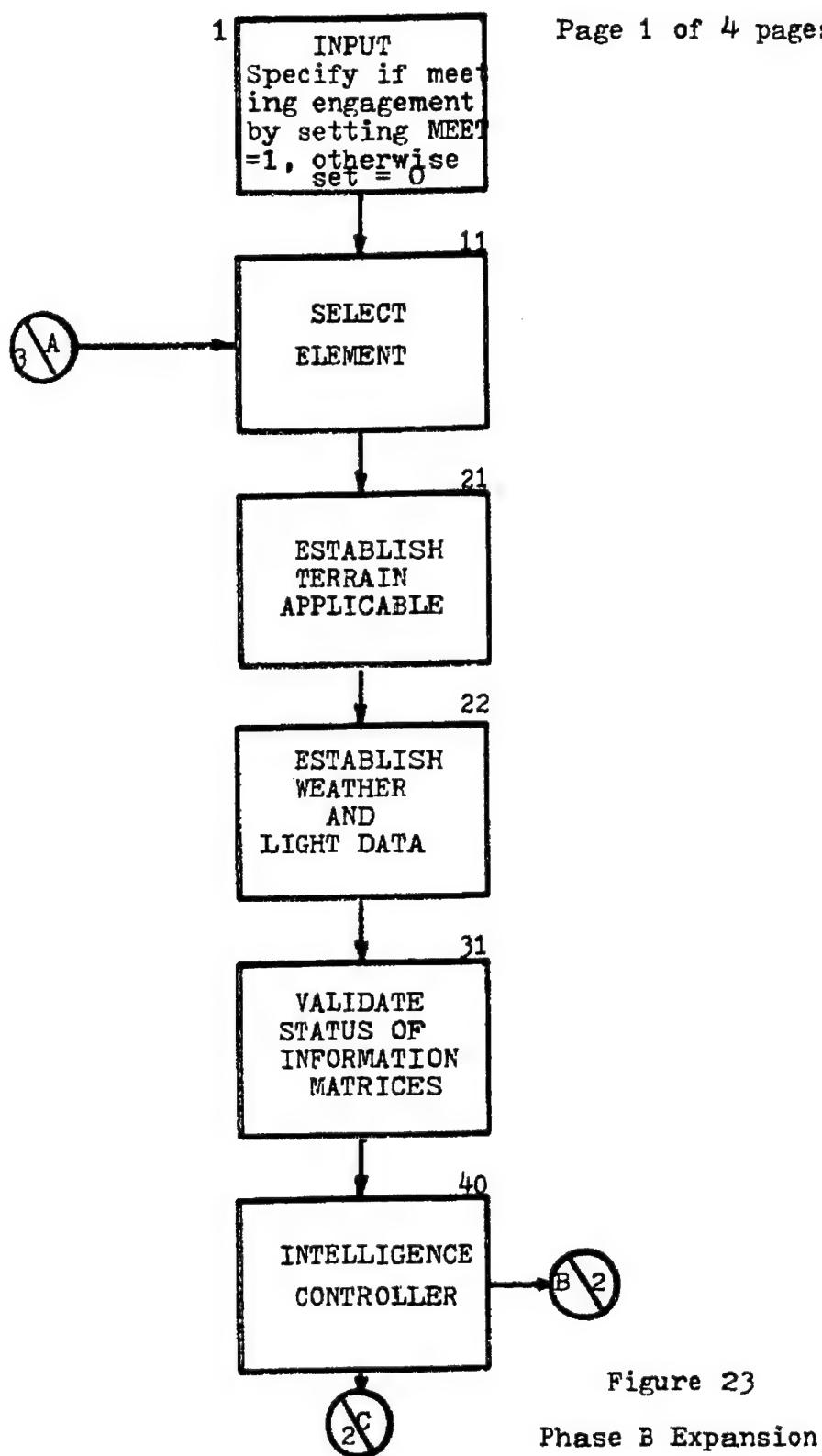


Figure 23  
Phase B Expansion

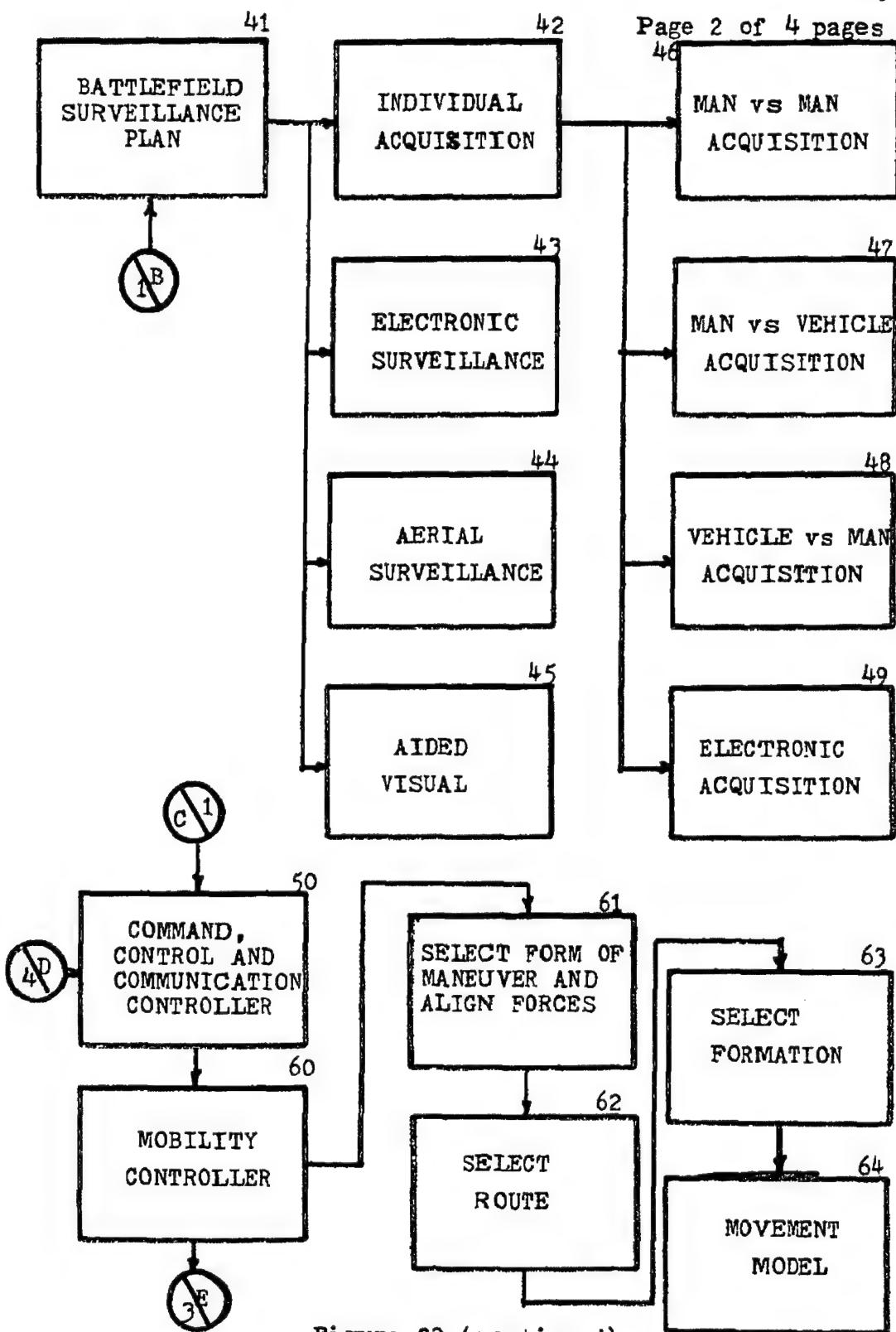


Figure 23 (continued)

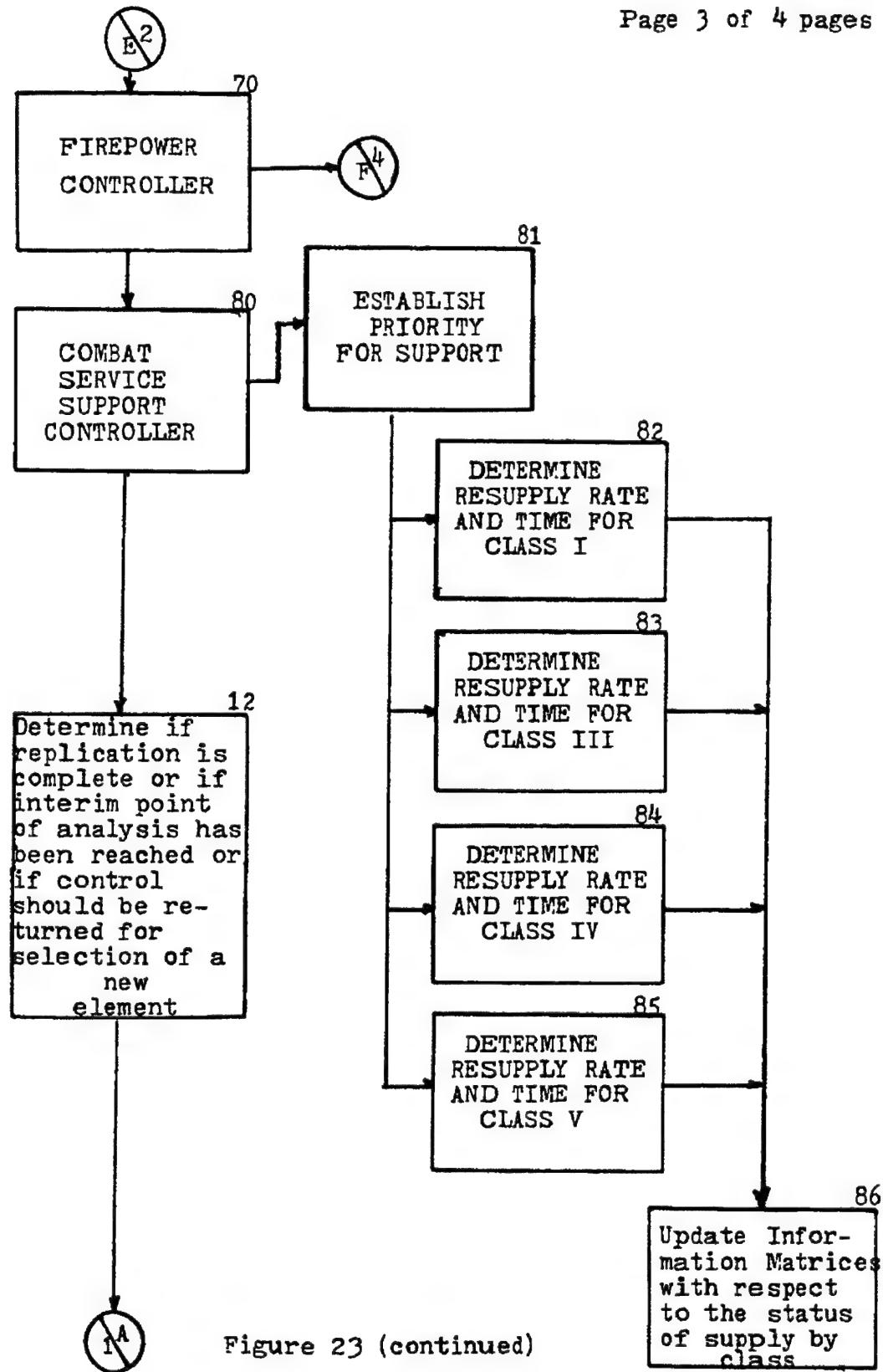
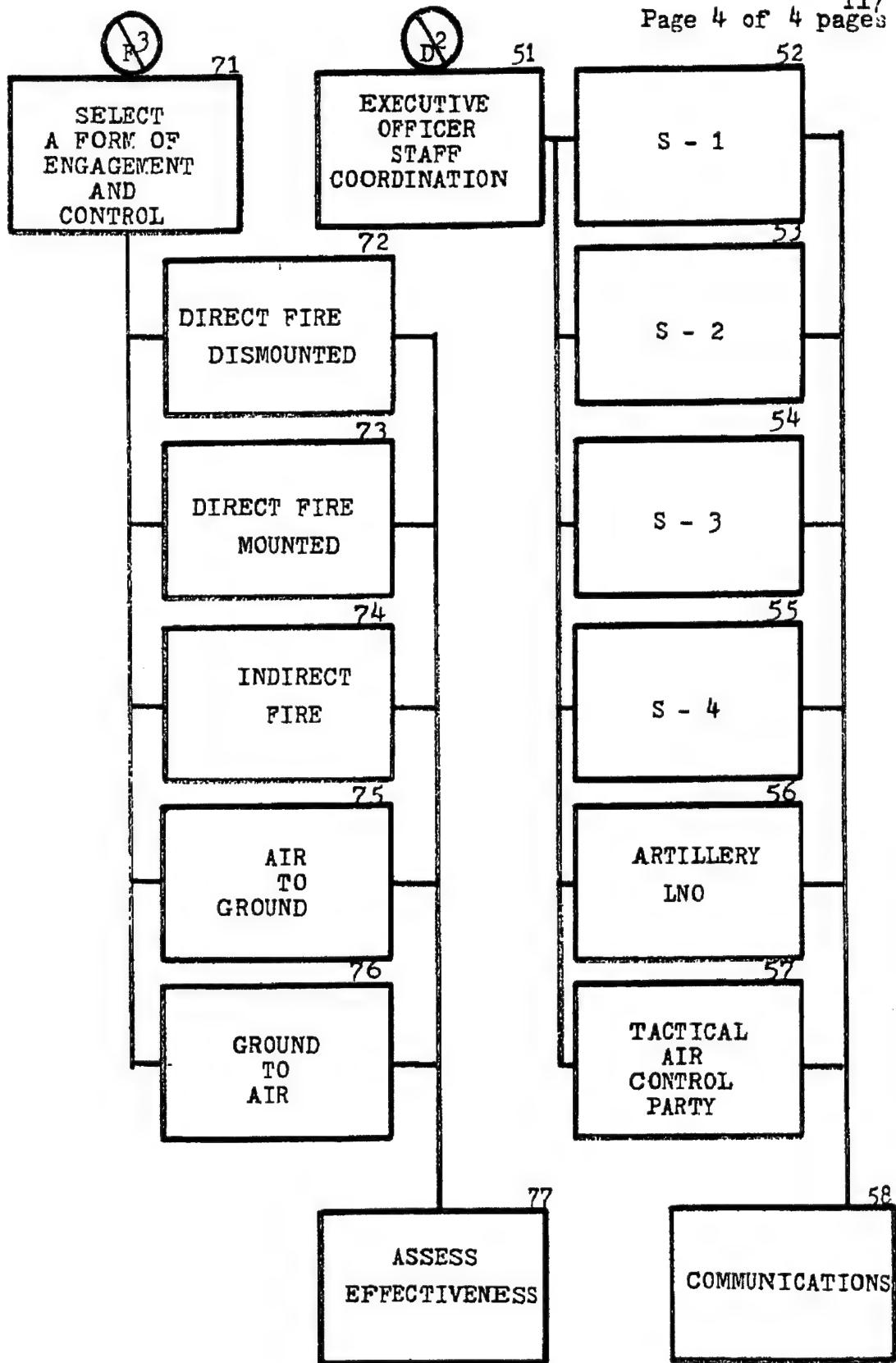


Figure 23 (continued)



tion of the major subprograms referenced. This expansion should serve to illustrate how the program can be compartmentalized to permit simultaneous development of major subprograms once a tentative framework has been developed here. This portion of the report will provide that minimum essential information required to support this independent development effort and to illustrate the form of detailed documentation required to adequately prepare the final program. This executive routine is similar to that which exists in the ASARS Battle Model.

Appendix B contains the detailed Phase C expansion sheets, system flowchart diagram, computer listing and demonstration exercise. Detailed information required and returned at each subprogram call are discussed in the appropriate portions of Chapter V.

#### CONCLUSIONS

This chapter has presented the detailed development of the executive routine of the combined arms model. A type task force, intentionally complex, was used as a vehicle for selecting a method of program control. The form described was Event Sequenced Time Constrained with a level of resolution to the Squad/Tank/Aerial/Platform/Crew Served Weapon Level. The ASARS Battle Model was used as a vehicle to discuss the operations, in general terms, of large scale computer simulations and describe

requirements for both the development of the executive routine and documentation supporting the entire program. With this information as a point of departure the three phases of development (A through C) were presented to describe the program's development, documentation and execution.

## CHAPTER V

### MODEL DEVELOPMENT REQUIREMENTS

#### INTRODUCTION

This chapter will take each of the major subprograms described in the executive routine and expand the discussion of each. Existing programs which support the subroutine functions of interest will be reviewed and their integration, where appropriate, will be described. As required, research and/or development needs will be identified and an approach to this development effort will be presented.

#### ENVIRONMENT DESCRIPTION

##### Terrain

Representation of terrain. Realistic terrain representation has been described as one of the major deficiencies of many existing operational models. Since 1965, the DYNTACS program concept, significant advances in this field have been realized. Perhaps the ultimate in realistic representation has been achieved by the SIAF reconnaissance program. This program describes a continuous surface by generation of a polynomial description of

a grid square. Although this method provides a very realistic representation of relief it is quite expensive with respect to computer storage capacity and running time. A somewhat less precise yet relatively high approximation of terrain has been realized by the DYNTACS family of models which generates planar surfaces in the form of triangles made up of  $\frac{1}{2}$  of a grid square. Additional potential has been provided these systems of representation through the Defense Mapping Agency (DMA) digitized map series. A program to convert the digitized data into a more compatible FORTRAN IV program has been developed which facilitates quick loading of different geographic areas.<sup>1</sup> The resolution of terrain is dictated by elevation data available from DMA at 6.25 meters and any multiple thereof. This relief data describes what will be called Macro terrain. The ASARS Battle Model uses these techniques to input the required Macro terrain. Once the raw elevation data is input there is a need to divide the rectangle of desired resolution by a diagonal to form a triangle and thus increase the capability of generally describing relief as a tilted planar surface.<sup>2</sup> The ASARS

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<sup>1</sup>U.S. Army Combat Developments Command, System Analysis Group. TR 2-73, Automated Preparation of Digital Topographic Data (Fort Belvoir, Virginia: February 1973)

<sup>2</sup>Daniel Howland and Gordon M. Clark, The Tank Weapon System - Annual Progress Report, June 1966. Department of Industrial Engineering, The Ohio State University. (Columbus, Ohio: June 1966) Chapter 3.

Battle Model program has an acceptable program for the Macro terrain except for its manner of assigning the diagonal direction which will describe the triangular plane. The ASARS Battle Model assigns the direction of this diagonal (upper left to lower right vs. upper right to lower left) randomly. It is suggested that this assignment process should be logical rather than random. A program should be applied in a preprocessor which compares the four corners of a grid square and draws a diagonal between the opposite corners with the least absolute difference in elevation. This will cause the major apparent variation in elevation within a grid square to be approximated within the surface of two planes.

The presentation of Macro terrain takes the initial first step in representation of the terrain and will adequately treat elevation and slope. Minor variations in surface elevations as well as vegetation and soil composition are also relevant and must be treated. This treatment is called Micro terrain. The ASARS Battle Model in conjunction with the SIAF program offer an acceptable manner of micro terrain treatment. The vegetation and surface condition treatment by the ASARS Battle Model applying the classes of vegetation documented in the SIAF program should be used.

Terrain Cover. The determination of the potential of intervisibility between two points on the battlefield

is a basic type of subroutine which will be required by several other programs. Due to its frequent use, this program, like the following vegetation cover routine, should be in the executive routine primary call area. The ASARS Battle Model has an excellent terrain cover subroutine, XLOS, which should be used.

Vegetation Cover. This subroutine must be capable of determining the potential for intervisibility between two points on the battlefield in consideration of vegetation. The ASARS Battle Model subroutine, VLOS, does the best job of making this determination in the field. The DYNTACCS and SIAF programs, having a most advanced treatment of terrain, consider a woodline as opaque. The ASARS Battle Model VLOS subroutine considers the probability of penetrating the woodline as a function of the SIAF classification of the vegetation. The ASARS Battle Model VLOS subroutine should be used.

#### Weather

In addition to Terrain and status of forces reported on earlier, the weather data will be required by a large number of subprograms. The SIAF program has gone to great lengths in modeling weather. The SIAF level of detail is necessary for the SIAF program but would be too expensive for use in terms of storage and running time in the Combined Arms Model. A scaling down of detail has

been developed for integration into the ASARS Battle Model and this program should be used in the Combined Arms Model.<sup>3</sup> This program adjusts factors used in the intelligence function in response to weather and light data to give the program a day, night and all weather capability.

#### INTELLIGENCE

This is the area that will require a major research and test effort in support of the program. One of the major subordinate elements of the intelligence function, Target Acquisition, has been identified by a select DA level Models Review Committee as an area of research deserving first priority of effort.<sup>4</sup> Detailed and accurate modeling of this function is a prerequisite for successful modeling of the other functions due to their dependence on intelligence for information. This modeling effort should be started early in the program as it will require the greatest development time and should concentrate on the areas described below.

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<sup>3</sup>U.S. Army Combat Developments Command, Infantry Agency. Feasibility of Modeling Operations Under Conditions of Reduced Visibility in the ASARS II Program. (Fort Benning, Georgia: February 1973)

<sup>4</sup>Department of The Army. Review of Selected Army Models. (Washington, D. C. May 1971), p. VIII-7.

Target Acquisition

General. It is highly desirable to develop a target acquisition subroutine which will model the acquisition process for all elements on the battlefield. If this proves infeasible then the principle determinants of acquisition must be consistent across specialized subroutines. The target acquisition studies completed by the Human Resources Research Office (HUMRRO) in support of the ASARS II Study Program successfully identified the significant variables, affecting target acquisition. The HUMRRO study identified these variables as: Obscuration, Range, Target Speed, Contrast and Illumination.<sup>5</sup>

Target Acquisition. The problem at hand in the field of target acquisition is no longer one of knowledge but instead one of integration, aggregation and validation. A number of specialized studies have expanded the field of knowledge in varying detail for each study. The need exists to integrate these efforts, expand the acquisition process to reflect acquisition of units in addition to single elements and finally to validate the resultant mathematical relationships. The Intelligence subprogram will be provided necessary information with respect to

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<sup>5</sup>U.S. Army Combat Developments Command. ASARS II, Second In-Process Review, 15-16 December 1971, After Action Report. (Fort Benning, Georgia: 22 December 1971) p. 4-J. 39.

intervisibility, light conditions and weather factors by the executive routine. The following constitute a recommended source of information from which to initiate the integration effort:

Man vs. Man:	ASARS II Study outline, to be distinguished from the currently existing model.
	SIAF - Reconnaissance Model.
Man vs. Vehicle:	ASARS II, SIAF, DYNCOM, DYNTACS-X.
Vehicle vs. Man:	DYNCOM, DYNTACS-X.
Electronic Acquisition:	ASARS II Battle Model.

Electronic Surveillance. This portion of the intelligence subprogram should provide for the dynamic development and direction of a battlefield electronic surveillance plan. The model should concentrate on the electronic warfare, radar and sensor means of acquiring information as well as consideration of electronic counter-measures and electronic counter-counter measures. The program should be capable of accepting all types of existing and developmental systems to present an inte-

grated electronic battlefield surveillance plan. Although some work at modeling systems has been accomplished, the dynamic surveillance plan development will necessarily be new.

Aerial Surveillance. This capability must be modeled in such a manner as to support the S-2 developed collection plan. This means of surveillance has been singled out because of its internal complexity and relatively high contribution to the overall collection effort. The aerial surveillance routine currently used in the DYNTAC-X (DYNCOM) program should be expanded to include tactical Air Force capabilities as well as Army Aviation fixed wing capabilities.<sup>6</sup>

Aided Visual. The recent advent of sophisticated equipment enhancing the individual's acquisition capability in both day and night operations required added emphasis in this model development effort. The affects of these aids can be integrated into the existing acquisition routines by adjustment of factors which determine the probability of acquisition. A framework of the logic recommended is presented in a concept for the modeling of

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<sup>6</sup> Clark and Hutcheson, The Aerial Platform Operations Module (DYNCOM Documentation) (Columbus, Ohio: May 1971).

combat under conditions of reduced visibility.<sup>7</sup> In this study a target's relative contrast was increased to represent the use of a hypothetical thermal viewing device with its theoretical foliage penetration capability.

#### MOBILITY

##### General

This subroutine will dynamically select a route for movement, formation and maneuver unit composition and scheme of maneuver. Given these leader-directed actions, control will pass to a movement submodel which will actually move the relevant elements on the battlefield in accordance with the plan developed. Three of these actions have been extensively modeled and are readily available. The fourth, dynamic maneuver, has not yet been adequately modeled, however, the decision logic necessary for its development is readily available in published doctrinal manuals.

Dynamic Maneuver. The combat maneuver unit will take prescribed actions with respect to maneuver, dependent upon a given set of input conditions. As a function of maneuver unit, level of command and number of subordi-

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<sup>7</sup>U.S. Army Combat Developments Command, Infantry Agency, Feasibility of Modeling Operations Under Conditions of Reduced Visibility in The ASARS II Program. (Fort Benning, Georgia: February 1973). p. 4-B-1.

nate maneuver units available a finite number of maneuver options will exist. The course to be followed in this new modeling effort is to wargame the task force described in Chapter IV and define the options available to a given level of command for all possible conditions. Branching on these situational factors should then lead to reorganization of maneuver units based upon the accepted response to the situation. This branching will have to be force oriented to account for variations in tactical doctrine between red and blue forces. Although this development effort is new, the magnitude of effort required is considered less than that required for the acquisition effort. The DYNTACS model with selected dismounted maneuver considerations from the ASARS Battle Model should be the point of departure. The force oriented movement logic of the SIAF program holds great potential for solution to this overall dynamic maneuver problem.

Route Selection. Upon specification of maneuver unit composition a route for the unit's movement must be selected. Both the DYNTACS and ASARS programs have comparable selection logic and either may be used. This program will make extensive use of the intervisibility routines in the executive routine call level.

#### Formation Selection

The selection of a formation should follow the

maneuver scheme and route selection process. The ASARS Battle Model has expanded upon the DYNTACS formation selection logic and is preferred. Considerations of terrain, visibility, known threat and fire control must be integrated.

#### Movement

A movement model will be entered by every element scheduled for a movement event. The existing movement model in the ASARS and DYNTACS models is considered adequate with the addition of rate of movement degradation factors considering soil configuration and light conditions.

### FIREPOWER

#### General

This portion of the model requires a major modeling effort. The controller of this function will dynamically generate firing assignments for subordinate elements and control the fire of these elements. The Firepower Controller will route the current element to one of five subordinate execution models where the actual firing of the appropriate systems will be undertaken. Finally, after each engagement, or when assessment of effects is called by the executive routine as a special event, control will pass to an effects model, called the casualty assessment model.

Firepower Controller

This subprogram will be entered only by current elements in leadership positions and will represent the thought process of the leader in considering the dynamics of the situation at any point in time and generating firing orders and control to subordinate levels of command. The ASARS Battle Model, FCONTR, has excellent basic leadership logic which should be expanded to include the other weapons systems not treated in ASARS but required in the combined arms model.

Execution Models

Direct Fire Mounted/Dismounted. A specific execution model will be entered by the type of weapon being fired. The appropriate execution submodel will use the environmental factors available from the executive routine level of call as input to one or more Army Material Command basic models. The Weapons Command Technical Note RDR-TN3-72 should be used to initially guide selection of the appropriate model to be incorporated.<sup>8</sup> Some of these models will have to be modified to insure that the distribution of casualty-producing affects about the target area are adequately presented. This general term of "casualty-

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<sup>8</sup>U.S. Army Weapons Command. A Survey or RD&E Mathematical Models/Computer Programs In the U.S. Army Weapons Command TN3-72 by Capt. Richard H. Moushegian and Tonney H. M. Hung. (Rock Island, Illinois: April 1972).

"producing affects" is intentionally used to permit the introduction now, or at some future time, of weapon systems that employ other than the conventional kinetic energy transfer means of producing casualties. If some form of radiation from a nuclear weapon or effect from a chemical weapon is to be assessed, the concentration of the casualty producing agent in the target area must be quantified. Further, the distribution of the more conventional fragments in the target area must also be known to support subsequent assessment of suppression and casualty production. In all cases the proven WECOM models should form the basis for the development effort. This requirement is further evidenced due to need for input data to support a model selected.

Indirect Fire. The indirect fire systems will have to be explicitly modeled in a level of detail comparable to the mounted/dismounted direct fire systems. This is a necessary prerequisite as a major anticipated application of this program will be trade off analysis between and within direct/indirect fire systems. The integration of the DYNTACS-X artillery and counter-battery models should adequately cover this area.

Air to Ground. Each of the two ship systems (Army and Tactical Air) described in Chapter IV will have to be modeled at a level of detail comparable to the other

execution models for the same reasons of trade-off analysis stated earlier. The DYNTACS-X aerial platform subroutines provide the logic necessary for use in this program but should be expanded to include the selected capabilities of the Aerial Weapons Effectiveness Simulation (AWES).<sup>9</sup>

Ground to Air. To provide the proper balance on the battlefield, air defense operations must also be modeled at a level of resolution comparable to the other systems. The DYNTACS-X air defense models are considered adequate and can be simplified for inclusion in the model. Air to air engagements should not be necessary and may be excluded from the program.

#### Effectiveness Assessment Models

General. The effectiveness assessment models must be capable of taking the output of the execution programs and assessing the effectiveness of the fire in terms of suppression and casualty production. As the need existed in the execution programs to treat weapon systems individually, the need exists in the assessment programs to evaluate effectiveness on a common base.

Suppression. The further research into the

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<sup>9</sup>Combat Operations Research Group. Aerial Weapons Effectiveness Simulation (AWES). (Fort Belvoir, Virginia: November 1968)

phenomenon of suppression was identified by the select Models Review Committee as one of the six areas warranting priority effort.<sup>10</sup> Significant research into this phenomenon has been accomplished in support of the ASARS study effort and is reported on in the form of two heavily documented final reports by Defense Science Laboratories of Litton Systems Inc.<sup>11</sup> A significant benefit was gained by having the same research organization complete this study effort. A comparable treatment of suppression across a wide band of representative systems was generated. The integration of this study effort into the ASARS Battle Model is not yet complete, however, the logic for such an integration is presented in a draft pamphlet published by the Infantry Agency of Combat Developments Command entitled Concepts for Integration of Suppression and Casualty Assessment Into the ASARS II Battle Model.<sup>12</sup>

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<sup>10</sup> Department of the Army. Review of Selected Army Models (Washington, D. C. May 1971). p. VIII-7.

<sup>11</sup> S.A. Kishnick and J.O. Duffy. The Identification of Objective Relationships Between Small Arms Fire Characteristics and Effectiveness of Suppressive Fire. (Litton Mellonics, Sunnyvale, California: April 1972).

Ralph P. Winter and E. Robert Clavis. Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units. (Litton System Inc., Sunnyvale, California: 31 January 1973).

<sup>12</sup> Concepts for Integration of Suppression and Casualty Assessment Into the ASARS II Battle Model (Draft). USACDC Infantry Agency (Fort Benning, Georgia: March 1972).

Casualty Assessment. A common factor across weapon systems causing casualty production must be sought to enable the common assessment of casualties in support of earlier referenced trade-off analysis. A concept suggesting kinetic energy transfer as this common thread has been proposed and the logic of its development outlined. Although the concept appears feasible it will require extensive revision of the AMSAA data base and further testing to gather empirical data. The development of a common method of casualty assessment is critical to the successful analytic trade-off of systems and should be pursued as required.<sup>12</sup>

#### COMBAT SERVICE SUPPORT

The task to be undertaken in this subprogram development is that of integrating logic which will accomplish the resupply of ground forces through both ground and aerial means. Programs exist which explicitly model the movement of supplies to the battlefield area by either ground or aerial means. The logic to represent a battalion level supply action in a hostile environment will be required. It is envisioned that supply, maintenance and medical elements will be dynamically moved in the rear portions of the battlefield areas performing their principal functions. These elements must be moved in such a manner that their realistic capabilities can be repre-

sented while they are subjected to acquisition and engagement by the opposing forces. Resupply and/or replacement will be accomplished by the updating of status of forces arrays in the executive routine. The programs developed in support of the Airlift Simulation Study<sup>13</sup> and the Analysis of Opportunities for the Reduction of Tactical Vehicle Requirements Through Pooling Study<sup>14</sup> should be simplified to represent battalion level force capabilities from the battalion/task force rear boundaries forward. These programs can in turn be used to generate input data to the combined arms models.

The combat engineer functions in the areas of barrier construction and breaching should be modeled with a level of detail comparable to the supply and maintenance elements. Time and resource dependent rates of construction should be dynamically determined as a function of existing conditions to include hostile action.<sup>15</sup>

In actual combat situations, reserve forces, combat support and combat service support units make pro-

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<sup>13</sup>U.S. Air Force Airlift Simulation Study, Programs Description and User's Manual (Langley Air Force Base, Virginia: February 1969)

<sup>14</sup>Research Analysis Corporation. Analysis of Opportunities For The Reduction of Tactical Vehicle Requirements Through Pooling. (McLean, Virginia: April 1971).

<sup>15</sup>Combat Operations Research Group. The Construction Submodel For The Service Support War Game. (Fort Belvoir, Virginia: 30 May 1967).

vision for rear area protection (RAP). RAP is a function that is normally accomplished on an area basis and on occasion requires the allocation of combat power in the form of combat maneuver units. The RAP mission includes rear area security and damage control activities at the combat battalion/Task Force level. At this level the rear area of the unit requiring RAP is, through design, small. Despite its relatively small area of application the necessity of this function often significantly impacts on the overall unit combat effectiveness. Significant factors required for modeling this function, as well as their interaction, are described in the Rear Area Protection Submodel For The Service Support War Game.<sup>16</sup>

#### Command, Control and Communications

This subprogram calls for the detailed modeling of each of the staff functions described in Figure 23 (page 4) of Chapter IV. The explicit modeling of the staff functions for purposes of use in a combat simulation has not been attempted. The first, and to date most confounding, problem associated with this or any related modeling effort is the detailed description of the system. This all important first step has been taken in the Tactical

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<sup>16</sup> Combat Operations Research Group. The Rear Area Protection Submodel For The Service Support War Game. (Fort Belvoir, Virginia: 14 March 1967).

Operation System (TOS) and Integrated Battlefield Control System (IBCS) Study efforts.<sup>17</sup> The processing of elements through these staff functional areas will require time assessments for the staff functions. Data necessary to support this assessment of time for a variety of Tactical Operations Center (TOC) configurations is required. Data of this type has been collected by project MASSTER in support of the TOS/IBCS testing program dating back to CPX 3A-D conducted at Fort Hood, Texas in 1970-1971.

The decision-making process is identical to that well documented in any good textbook addressing the subject of decision analysis.<sup>18</sup> The eleventh military operations research symposium convened in Durham, North Carolina in the spring of 1972 devoted four full days to the subject of Risk Analysis and provides additional specialized information that will be needed for modeling this area.<sup>19</sup>

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<sup>17</sup> U.S. Army Combat Developments Command, Institute of Combined Arms and Support. Refinement of the IBCS Concept, IBCS Phase I. (Fort Belvoir, Virginia: April 1971).

<sup>18</sup> Howard Raiffa, Decision Analysis (Massachusetts: Addison-Wesley July 1970).

<sup>19</sup> Department of the Army. Offices of the Chief of Research and Development. The Proceedings of the U.S. Army Operations Research Symposium, 15-18 May 1972. (Durham, North Carolina)

## MANAGEMENT

The management organization, perhaps more than the technical problems to be faced, can dictate the feasibility of such a modeling effort. The technical problems are relatively simple in comparison to the understanding by the analysts of the phenomena being modeled. Although the program has intentionally been broken down into a series of more manageable, relatively independent, subprograms for possible contract effort, the integrating body must be made up of qualified combat arms military operations research qualified personnel. This management body with a single qualified program manager must be retained intact for the duration of the project. This point cannot be overemphasized. Retired military personnel are not adequate since the program requires detailed recent experience. The analysts involved in the Program Manager's Office must be proven, qualified combat arms leaders. These men should then have been educated in the technical science areas required for the program. If the program cannot be developed exclusively by the military analysts previously described then contractual effort for portions of the program to private corporations who have demonstrated proficiency in specific fields is a viable alternative.

## CONCLUSION

The overriding conclusion that should be drawn from this chapter is the fact that little in the development effort of this model is truly virgin territory. Considerable research has already been accomplished in each of the areas needed. These developments, as noted by the references, are relatively new and have succeeded in closing many of the data and development gaps identified by the select Model Review Committee.

## Chapter VI

### CONCLUSIONS

#### GENERAL

Although the need for a battalion level combined arms stochastic simulation was not extensively supported in Chapter I, the subsequent analysis repeated reference to existing problems being faced by the Army in the area of material acquisition and force structuring has demonstrated the critical need for such an operations research systems analysis tool. The potential application of such a tool has been described in Figure 1 of Chapter I.

The hypothesis that the bulk of the technology required for such a model development exists and that this technology can be integrated through an executive routine has been established for evaluation. The remainder of this research effort then concentrated on establishing criteria for evaluation of portions of this hypothesis and to guide the theoretical development of a model. The major areas requiring evaluation for proper testing of the hypothesis were identified as:

Feasibility of describing the Battalion/Task Force system in sufficient detail to enable modeling.

Feasibility of measuring the effectiveness of

units through a combat simulation that could relate to actual organizations.

Suitability of existing programs to accomplish the purpose.

Feasibility of developing an executive routine that could integrate desirable aspects of other models.

Identification of areas requiring additional research effort and specification of a methodology to accomplish the research and associated development effort.

#### DESCRIPTION OF THE SYSTEM AND MEASURES OF EFFECTIVENESS

Chapter II has demonstrated that the system of interest can be described at a level of detail necessary to permit modeling. Measures of Effectiveness were developed which would support the methodology presented for the conduct of a type study. These measures were used to conduct subsequent analysis of existing programs. The conclusion to be drawn at this point is that the system can be described and measured in adequate detail to accomplish the objective of a type study presented in Figure 1.

#### EXISTING PROGRAMS

Chapter III served as an in-detail review of a number of relevant programs. This chapter serves as a convenient compendium of models with potential application

to the type of combined arms evaluation described listing the strengths and weaknesses of each program. This chapter has enabled the conclusion that many highly specialized programs in support of specific studies exist. These normally model specific functions of combat for particular units of interest in great detail. With minor exceptions, virtually all the functions of land combat at approximately the level of organization of interest have been successfully modeled. Although these programs are highly specialized they do support the development of a combined arms model. The DYNTACS family of models are major contributors to this effort. A detailed list of the DYNTACS related documentation with DDC control numbers is at Appendix C.

#### EXECUTIVE ROUTINE

An existing model, the ASARS Battle Model, was intensively analyzed to describe the logical requirements of an executive routine. Centering on the functions of land combat, and in recognition of the desirability of using existing programs, an executive routine was used as a vehicle to present a method and detail of documentation required in the program development. The executive routine was developed and its execution demonstrated. The executive was built in a manner which enables independent development of subordinate routines providing interface

between programs through the executive routine. This demonstration leads to the conclusion that an executive routine of the type which would be required for a combined arms model is technically feasible.

#### ADDITIONAL RESEARCH AND DEVELOPMENT

With the exception of four areas, significant additional research and development effort in support of the combined arms model is not needed. These four areas, in an expected order of difficulty, are:

Acquisition and Surveillance

Casualty Assessment

Command and Control (to include staff functions)

Dynamic Maneuver

In each of these cases either a methodology has been presented or referenced which should be used in satisfying requirements. The ability to identify these problems as well as a concept for their reduction indicates that their solution, in at least a rudimentary sense, is within the state of the art.

#### CONCLUSION

It is concluded that the development of a battalion level combined arms stochastic simulation is within the state in existing technology.

## RECOMMENDATIONS

It is recommended that Department of the Army undertake the development of a combined arms battalion level stochastic simulation. Approval and implementation of the following specific recommendations will enable this program to be undertaken:

1. Designation of the developmental effort as a 5 year independent study effort to be completed in three phases.

Phase I - Expansion of existing methodology to include preparation of requests for contract proposals and awarding of contracts. (Duration 1 year)

Phase II - Contract completion and integration. Model completed and demonstrated. (Duration 2 years)

Phase III - Model Validation through field experimentation and sensitivity analysis. (Duration 2 years)

2. A project manager with a staff of 5 qualified military officers be assigned the project for the entire duration of the effort. The project manager should be responsive to DA Staff Level and have access and funds to integrate Army wide resources toward accomplishment of the objectives. Adequate programming and secretarial support will be required.

3. Priority for use of a CDC 6600 type computer be assigned to the project. (A CDC type computer is recommended based upon its current availability to the

Army R&D community. It is anticipated that work with the ASARS, DYNTACS and SIAF programs could well exceed the internal storage capacity of the CDC 6600. Other computers have demonstrated faster operation of large programs of this large size and foster a preference for use of a large third generation IBM or at least the CDC 7600 with a capacity of approximately 1.3M Bytes).

4. Contract funds be allocated to the project to permit contractual effort in the four major areas requiring additional research and development. It is estimated that contract efforts should be approximately \$500,000 over the five year period concentrated in the second and third years.

5. For purposes of evaluating the effectiveness of the development effort a specific study objective, of those offered in Figure 1 of Chapter I, should be assigned to the project. The statement of work should assign the project a specific objective however care must be exercised to insure that the objective does not compromise the general nature of the project.

**APPENDICES**

**APPENDIX A**

## APPENDIX A

### COMMON MAPPING

## ASARS II BATTLE MODEL

## COMMON MAPPING - Continued

## COMMON MAPPING = Continued

## COMMON MAPPING - Continued

SUBROUTINE	COMMON
1 POLURE	1
2 ADJUST	2
3 ANTEN	3
4 ASSESS	4
5 SHARD	5
6 ASSES	6
7 BATSM	7
8 ATTHE	8
9 BASUM	9
10 CASA	10
11 COAREX	11
12 COUNTIN	12
13 COMBNE	13
14 DESER	14
15 FORTW	15
16 FORTW	16
17 GETT	17
18 GETT	18
19 PRIMO	19
20 PTELOC	20
21 PSUPER	21
22 PSUPER	22
23 PSUPER	23
24 PRJAX	24
25 PRJAX	25
26 IDETR	26
27 IDETR	27
28 IDETR	28
29 IDETR	29
30 IDETR	30
31 IFRAM	31
32 INSTRU	32
33 INTSL	33
34 INTSL	34
35 INTSLP	35
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38 INTSLP	38
39 INTSLP	39
40 ISOPOD	40
41 ISQUD	41
42 ITEST	42
43 ITASCA	43
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62 ITATO	62
63 ITIME	63
64 ITLECA	64
65 ITLOS	65
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209 LPRT	209

#### COMMON MAPPING - Continued

## COMMON MAPPING - Continued

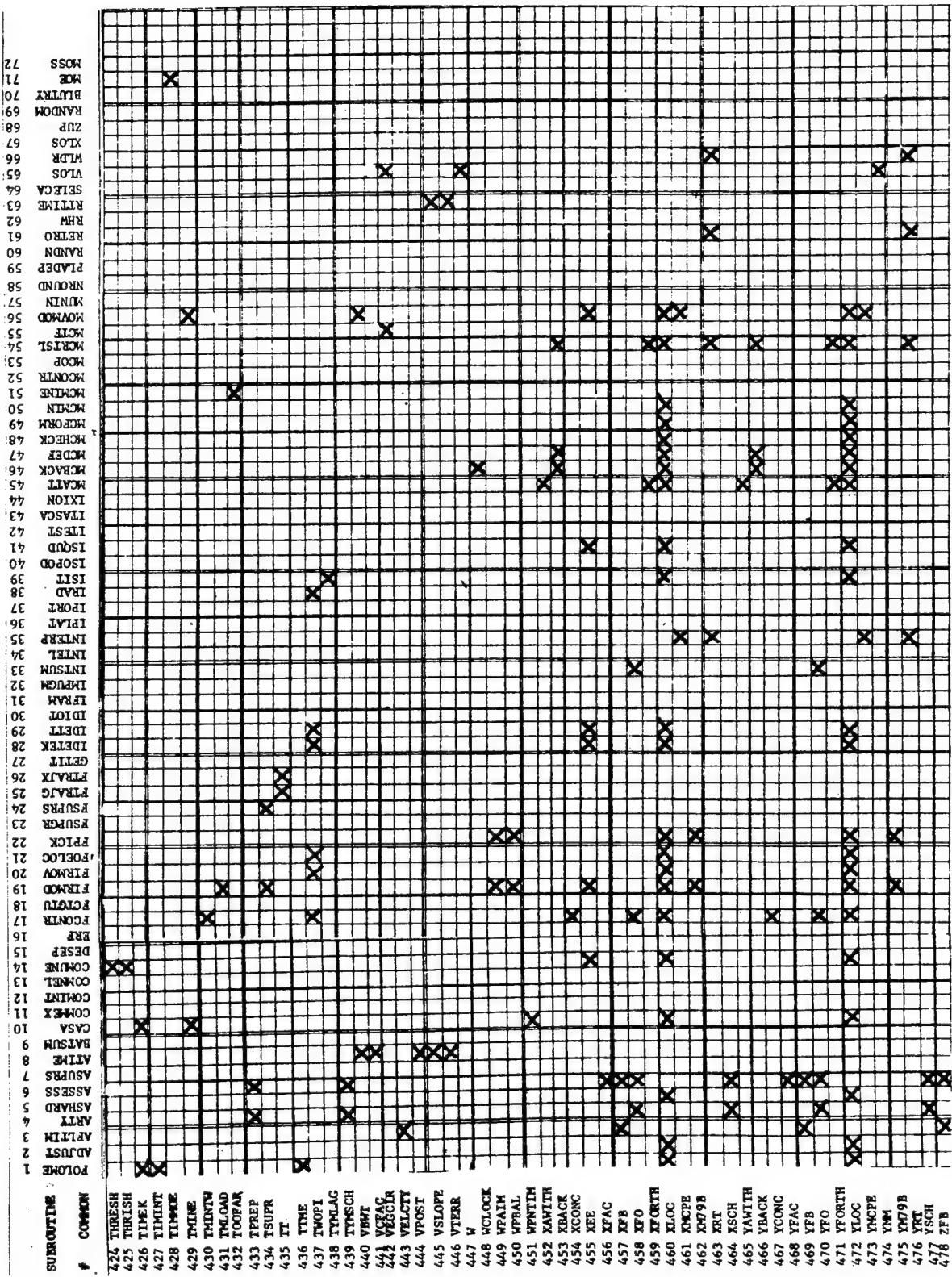
The figure is a grid-based map of the world, likely representing the distribution of various species. The grid consists of small squares covering the entire map area. Numerous 'X' marks are scattered across the grid, indicating the presence of specific species in certain regions. The y-axis on the left side of the map lists approximately 70 species names, and the x-axis at the bottom lists geographical regions. The 'X' marks are concentrated in certain areas, suggesting higher biodiversity or specific environmental conditions in those regions.

Species	Region
1. TOLONE	1. N. AMERICA
2. ADULTS	2. N. AMERICA
3. ADULTS	3. N. AMERICA
4. ASSESSES	4. N. AMERICA
5. ASSESSES	5. N. AMERICA
6. ATTEM	6. N. AMERICA
7. ATTEM	7. N. AMERICA
8. ATTEM	8. N. AMERICA
9. CAS	9. N. AMERICA
10. COUNTRY	10. N. AMERICA
11. COUNTRY	11. N. AMERICA
12. COUNTRY	12. N. AMERICA
13. COUNTRY	13. N. AMERICA
14. DESE	14. N. AMERICA
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17. ECOTR	17. N. AMERICA
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40. ISPOGD	40. N. AMERICA
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67. ZUP	67. N. AMERICA
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242. NAMCP	242. N. AMERICA
243. NAMCP	243. N. AMERICA
244. NAMCP	244. N. AMERICA
245. NAMCP	245. N. AMERICA
246. NAMCP	246. N. AMERICA
247. NAMCP	247. N. AMERICA
248. NAMCP	248. N. AMERICA
249. NAMCP	249. N. AMERICA
250. NAMCP	250. N. AMERICA
251. NAMCP	251. N. AMERICA
252. NAMCP	252. N. AMERICA
253. NAMCP	253. N. AMERICA
254. NAMCP	254. N. AMERICA
255. NAMCP	255. N. AMERICA
256. NAMCP	256. N. AMERICA
257. NAMCP	257. N. AMERICA
258. NAMCP	258. N. AMERICA
259. NAMCP	259. N. AMERICA
260. NAMCP	260. N. AMERICA
261. NAMCP	261. N. AMERICA
262. NAMCP	262. N. AMERICA
263. NAMCP	263. N. AMERICA
264. NAMCP	264. N. AMERICA
265. NAMCP	265. N. AMERICA
266. NADIST	266. N. AMERICA
267. NAMCP	267. N. AMERICA
268. NAM	268. N. AMERICA
269. NARZAN	269. N. AMERICA
270. NARCE	270. N. AMERICA
271. NARCTO	271. N. AMERICA
272. NARTEL	272. N. AMERICA
273. NARSG	273. N. AMERICA
274. NATT	274. N. AMERICA
275. NBSLSD	275. N. AMERICA
276. NCGRO	276. N. AMERICA
277. NCLOCK	277. N. AMERICA
278. NDIFP	278. N. AMERICA
279. NDEST	279. N. AMERICA
280. NEC	280. N. AMERICA
281. NELE	281. N. AMERICA
282. NEP	282. N. AMERICA
283. NET	283. N. AMERICA
284. NFARM	284. N. AMERICA
285. NFFLAG	285. N. AMERICA
286. NFPLAG	286. N. AMERICA
287. NFT	287. N. AMERICA
288. NFTFM	288. N. AMERICA
289. NFNTS	289. N. AMERICA
290. NGLEN	290. N. AMERICA
291. NHPS	291. N. AMERICA
292. NIN	292. N. AMERICA
293. NINLIN	293. N. AMERICA
294. NEPAL	294. N. AMERICA
295. NLD	295. N. AMERICA
296. NMET	296. N. AMERICA
297. NULS	297. N. AMERICA
298. NORFORM	298. N. AMERICA
299. NORFORM	299. N. AMERICA
300. NOMEEN	300. N. AMERICA
301. NORPTP	301. N. AMERICA
302. NOSE	302. N. AMERICA
303. NOX	303. N. AMERICA
304. NP	304. N. AMERICA
305. NPHASE	305. N. AMERICA
306. NPFLT	306. N. AMERICA
307. NPROJ	307. N. AMERICA
308. NRDBND	308. N. AMERICA
309. NRDSUP	309. N. AMERICA
310. NRGE	310. N. AMERICA
311. NRNDCN	311. N. AMERICA
312. NSQ	312. N. AMERICA
313. NSQDS	313. N. AMERICA
314. NSQE	314. N. AMERICA
315. NSTP	315. N. AMERICA

## COMMON MAPPING - Continued

## COMMON MAPPING - Continued

## COMMON MAPPING - Continued



**APPENDIX B**

## Appendix B

### Phase C Expansion Documentation

The purpose of this appendix is to present the detailed documentation required to support the phase C expansion. This appendix presents the recommended documentation detail considered essential to insure comprehension by model users as well as facilitating integration of the model and modification to the program as necessary.

The first significant documentation is a listing and definition of variables used in the program. In addition to the definition of the variable, input related comments are included as appropriate. This listing for the executive routine under development is presented in Table B-1.

The actual phase C expansion is accomplished in three column tabular form. The first column contains the FORTRAN IV programming chart. The second column explains the function of the program in column 1 while the third column explains variables introduced for the first time and peculiarities of inputs related again to the portion of the system chart in column 1. The numbers at the upper right hand quarter of the symbol in column 1 facilitate reference to the Phase A and B expansion as

well as assisting the explanation and input discussion in the remainder of the chart. This detailed expansion is presented in Figure B-1.

The third item in this phase of the expansion is a system flowchart. This chart presents in pictorial form the execution logic of the program in FORTRAN IV. The system flowchart is presented in Figure B-2.

The last item in this documentation package is a program listing. As a minimum this portion of the documentation should include the listing which has been accepted and compiled by the computer. In this particular case the program listing has been expanded to include dummy subroutines and data to demonstrate the operation of the program.

Table B-1  
Variables Used in Executive Routine

Name	Definition	Input Note
BATMAX	Maximum time battle will be permitted to proceed.	Input in seconds.
CLOCK(I)	Individual clock time.	Seconds-Set close to zero initially.
CLOCKA	Real simulation run time.	Initialize at zero.
CLOCKB	Real simulation start time.	Scenario input.
CLOCKC(K)	Time projected by FCONTR for impact of next artillery volley. K is index to indicate 1 for Side A and 2 for Side B.	Initialize as 1 second greater than BATMAX.
CLOCKS	Event start time used for storage with respect to current element.	N/A
ELOCX(I)	X coordinate of element I.	Enter start point for each element.
ELOCY(I)	Y coordinate of element I.	Enter start point for each element.
I	Element number of current element.	N/A
IDEAD	Internal working flag to indicate that the current element is due to be processed as a casualty in this event.	N/A

Table B-1 (continued)

Name	Definition	Input Note
IFECT(K)	Flag to route logic in FCONTR to assessment of artillery fire by Side K.	Initialize as zero.
ILEAD(I)	Leadership level for each element.	Input from scenario.
	Leadership Level -	
0	None	
1	Fire Team Leader	
2	Squad Leader	
3	Machine Gun Crew	
4	Machine Gun Section	
5	Platoon Leader	
6	Mortar Gun	
7	Mortar Gun Section	
8	Mortar Platoon Headquarters	
9	Artillery FO	
10	Company Commander	
11	Maintenance Section	
12	Supply/Admin. Section	
13	XO	
14	Command Tank	
15	Tank Section	
16	Heavy Tank Section	
17	Light Tank Section	
18	Tank	
19	Redeye Team	
20	Redeye Team Hqs.	
21	Surveillance Team	
22	Surveillance Hqs.	
23	Scout Section	
24	Scout Section Hqs.	
25	Anti Tank Squads	
26	Anti Tank Headquarters	
27	Tactical Aircraft	
28	Tactical Aircraft Flight	
29	Army Aircraft	
30	Army Aircraft Flight	
31	Engineer Platoon	
32	Artillery Piece	
33	Artillery FDC	
34	Artillery Maintenance	
35	Artillery Supply	
36	S-1	

Table B-1 (continued)

Name	Definition	Input Note
	37 S-2 38 S-3 39 S-4 40 XO 41 TACP 42 Artillery LNO 43 Aid Station 44 Evacuation Section 45 Maintenance Platoon 46 Communications Platoon 47 Support Platoon Hqs. 48 Mess Section 49 Supply Section 50 Transportation Section	
INTFLC(I)	Interrupt flag for Command, Control and Communications.	Initialize at zero.
INTFLF(I)	Interrupt flag for Fire-power.	Initialize at zero.
INTFLG(I)	Flag set in combat function subroutines to indicate that an event was interrupted.	Initialize at zero.
INTFLI(I)	Interrupt flag for Intelligence.	Initialize at zero.
INTFLM(I)	Interrupt flag for Mobility.	Initialize at zero.
IPICK1	Counter to record calls of FCONTR.	Initialize at zero.
IPICK2	Counter to record calls of current element's normal processing.	Initialize at zero.
IPICK3	Counter to record calls for Interim Summary.	Input at zero.
ISTEPA	Number of residual force step increments for interim analysis Side A.	Input at number of levels of RATAP desired. Do not exceed 5.

Table B-1 (continued)

Name	Definition	Input Zero
ISTEPB	Number of residual force step increments for interim analysis Side B.	Input at number of levels of RATBP desired. Do not exceed 5.
ISW	Working variable to indicate the type of processing required.  0 = Current element normal processing. 1 = Artillery impact event. 2 = Interim summary event.	N/A
JACK	Interim working variable to select current element.	N/A
K	Force side indicator 1 = A 2 = B	N/A
KOUT	Output mode identifies.	Dependent on computer system. Normally = 6.
LEMAN(I)	Maneuver unit of element I.	Dependent upon scenario.
LWP	Weapon code of current element used as an internal working variable.	N/A
LWPNC(I)	The weapon code for each element. This list will be similar to that of ILEAD(I) in that each unique combination of weapons by element grouping must be separately indexed.	From Scenario.
MAXT(MODE)	Maximum time length permitted for each mode of the simulation.	Seconds.

Table B-1 (continued)

Name	Definition	Input Note
MISION(MUN)	Mission assignment of each maneuver unit:  1 = Attack 2 = Attack Fire Support 3 = Defense 4 = Security 5 = Delay 6 = Withdrawal	From scenario.
MODE	Counter to reflect stepping of simulation to one of three levels of time constraint.	None.
MUN	Maneuver unit of current element.	N/A
MUNA	Total number of maneuver units for Side A.	Scenario.
MUNB	Total number of maneuver units for Side B.	Scenario.
MW	Element number of first element Side A.	N/A
MX	Element number of last element Side A.	N/A
MY	First element of Side B.	N/A
MZ	Last element of Side B.	N/A
NLD	Leadership level of current element.	N/A
NMIS	Internal variable to record the mission of current element's maneuver unit.	N/A
NTOTAL	Total number of elements in the simulation.	Scenario up to 250.
NUMA	Total number of elements on Side A.	Scenario.

Table B-1 (continued)

Name	Definition	Input Note
NUMB	Total number of element on Side B.	Scenario.
NW	Maneuver unit number of first maneuver unit Side A.	N/A
NX	Maneuver unit number of last maneuver unit Side A.	N/A
NY	First maneuver unit Side B.	N/A
NZ	Last maneuver unit Side B.	N/A
RA	Number of elements remaining on Side A. Updated by casualty assessment portion of FCONTR.	Set equal to NUMA.
RATA	Internal working variable to store percentage of force A remaining.	N/A
RATAP(ISTEPA)	Criteria for entering Interim summary of battle expressed as percentage of original force A remaining.	Plan for analysis will dictate points required.
RATB	Internal working variable to store percentage of force B remaining.	N/A
RATBP(ISTEPB)	Criteria for entering interim summary of battle expressed as percentage of original force B remaining.	Plan for analysis will dictate points required.
RB	Number of elements remaining on Side B. Updated by casualty assessment portion of FCONTR.	Set equal to NUMB.

Table B-1 (continued)

Name	Definition	Input Note
SA	Number of elements on Side A that started the simulation.	Set equal to NUMA.
SB	Number of elements on Side B that started the simulation.	Set equal to NUMB.
SUMTIM	Time in seconds at which next interim summary is to be prepared.	Set equal to TDMINT normally.
TIMEK(I)	Time at which element I is scheduled to die. Set in casualty assessment of FCONTR.	For all I initialize at large number.
TIMINT	Desired time interval between Interim Summaries.	Dependent upon plan of analysis.
TMAX	Internal storage of maximum event length due to mode constraint.	Initialize at large number. = 10000.
TMIN	Minimum time used for selection of next element for processing.	Initialize at large number. = 10000.
XLOC	X Coordinate of current element.	N/A
YLOC	Y Coordinate of current element.	N/A

Phase C Expansion of Executive Routine

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Page 1 of 21 pages

COMMONS INPUT, BATMAX, CLOCK(I), CLOCKC(K), CLOCKS, ELOCK(I), ELOCY(I), I, IDEAD, IFECT,  
ILEAD(I), INTFLC(I), INTFLF(I), INTFLG(I), INTFLI(I), INTFLM(I), IPICK1,  
IPICK2, IPICK3, ISTEPB, ISW, K, KOUT, LEWAN(I), LWF, LWPN(I),  
MAXT(L), MISION(M), MODE, MUN, MUNB, MW, MY, NZ, NLD, NMIS,  
NTOTAL, NUMA, NUMB, NW, NX, NY, NE, RA, RATA, RATAP(N), RATB, RATBP(N),  
RB, SUMTIM, TIMINT, TIMEK(I), TMAX, XLOC, YLOC, CLOCKA, CLOCKB

OTHER INPUT:

VARIABLES GENERATED: JACK, SA, SB, SUMTIM, TWIN

NARRATIVE: This executive routine reads in the input data, selects the current element, controls the processing of the current element checking periodically to determine if input conditions exist for preparation of output and terminates the program when appropriate.

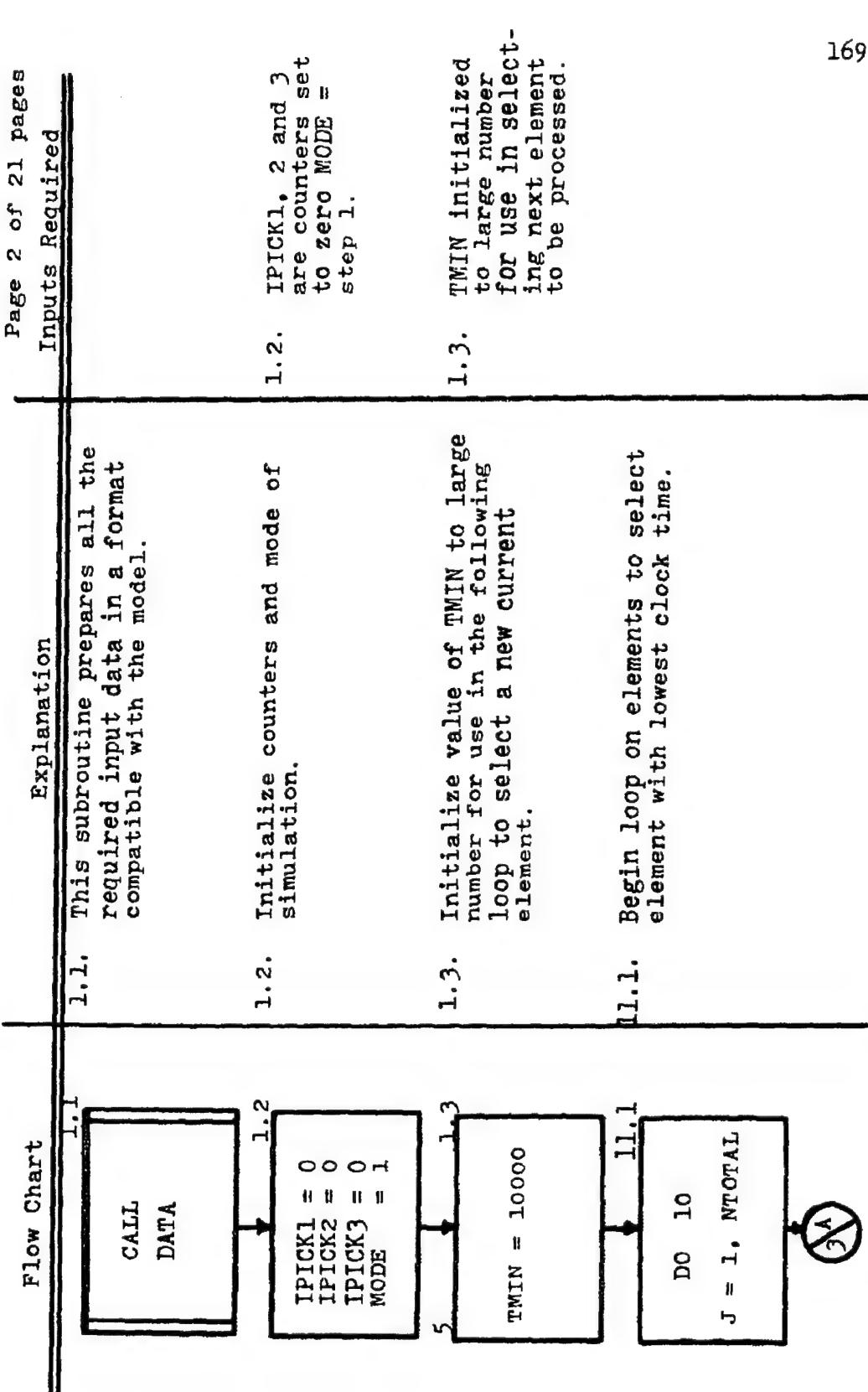
Figure B-1  
Phase C Expansion - Executive Routine

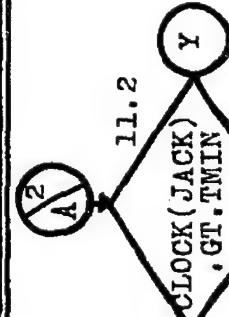
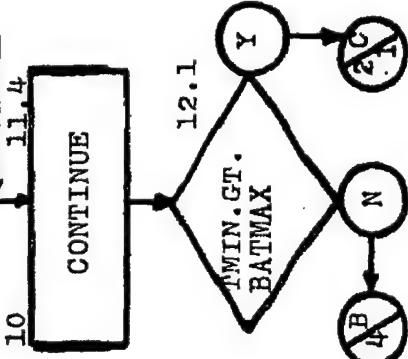
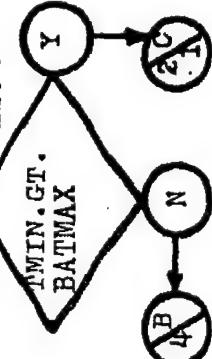
Flow Chart

Explanation

Page 2 of 21 pages

Inputs Required

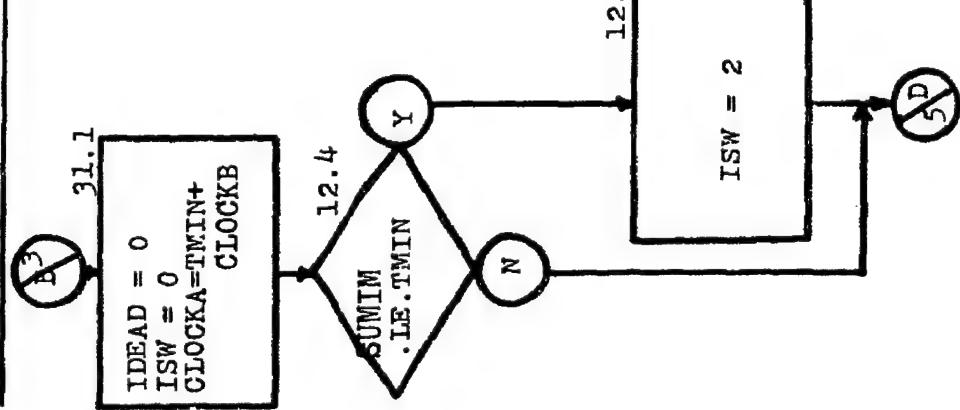


Flow Chart	Explanation
	11.2. Check each element and reject those with time greater than established minimum time.
	11.3. For those elements with a lower clock time than the previously set TMIN: a. Reset minimum time. b. Set TMAX equal to the maximum event time allowed as a function of mode. c. Select element JACK as the current element I. d. Set CLOCKS to CLOCK(I) time for later use in checking event time length.
	11.4. End Do Loop on elements.
	12.1. Check to see if maximum running time of simulation has been exceeded. If so - exit.
	12.2. BATMAX = maximum running time of simulation - input.

11.2. CLOCK = Individual clock time.

11.3. TMAX = maximum allowable event length as a function of MODE - Input.  
I = element number of current element selected.  
CLOCKS = event starting clock time for element I.

12.1. BATMAX = maximum running time of simulation - input.

Flow ChartExplanationInputs Required

31.1 Initialize flags and record clock times for later use.

12.4 Check to determine if interim summary should be prepared.

12.5 Set flag for interim summary preparation.

Explanation	Inputs Required
31.1 Initialize flags and record clock times for later use.	31.1 IDEAD=Flag to indicate if current element to be processed as a casualty. ISW=Flag to indicate type of admin. action required. ISW=0=Current element selected for normal processing. ISW=1=Artillery impact selected as event. ISW=2=Interim summary to be presented.
12.4 Check to determine if interim summary should be prepared.	CLOCKA=Simulation real time in seconds.

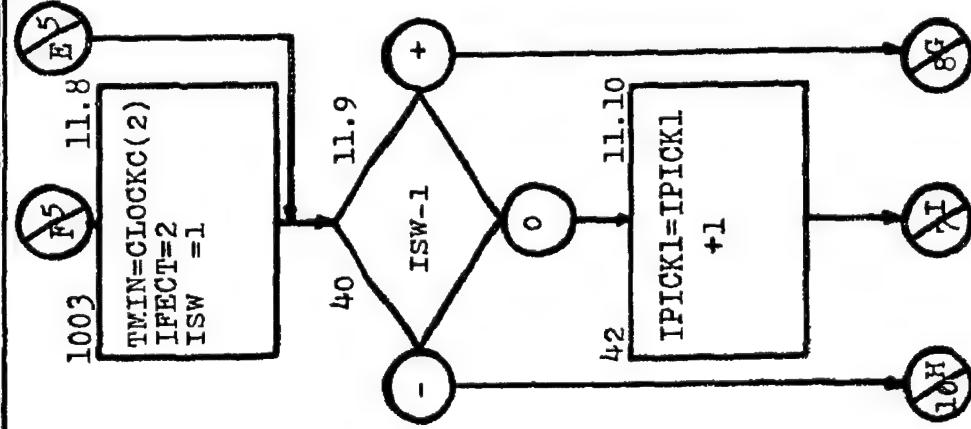
12.4

171  
SUMTIM=Time at which an Interim Summary is desired.

Flow Chart	Explanation	Inputs Required
	11.5 Check to see if a projected time for impact of artillery fired by side 1 is less than TMIN.	11.5 CLOCK(1) = Projected time of impact of artillery fire- from FCONTR L for side 1.
	11.6 If projected impact time is less than existing TMIN a. Set TMIN equal to this time b. Set IFECT Flag c. Set ISW Flag	11.6 IFECT=Flag to in- dicate artillery effectiveness re- evaluation re- quired in FCONTR for side 1 or 2 .
	11.7 Same as 11.5 for side 2.	

Page 6 of 21 Pages  
Inputs Required

Flow Chart      Explanation



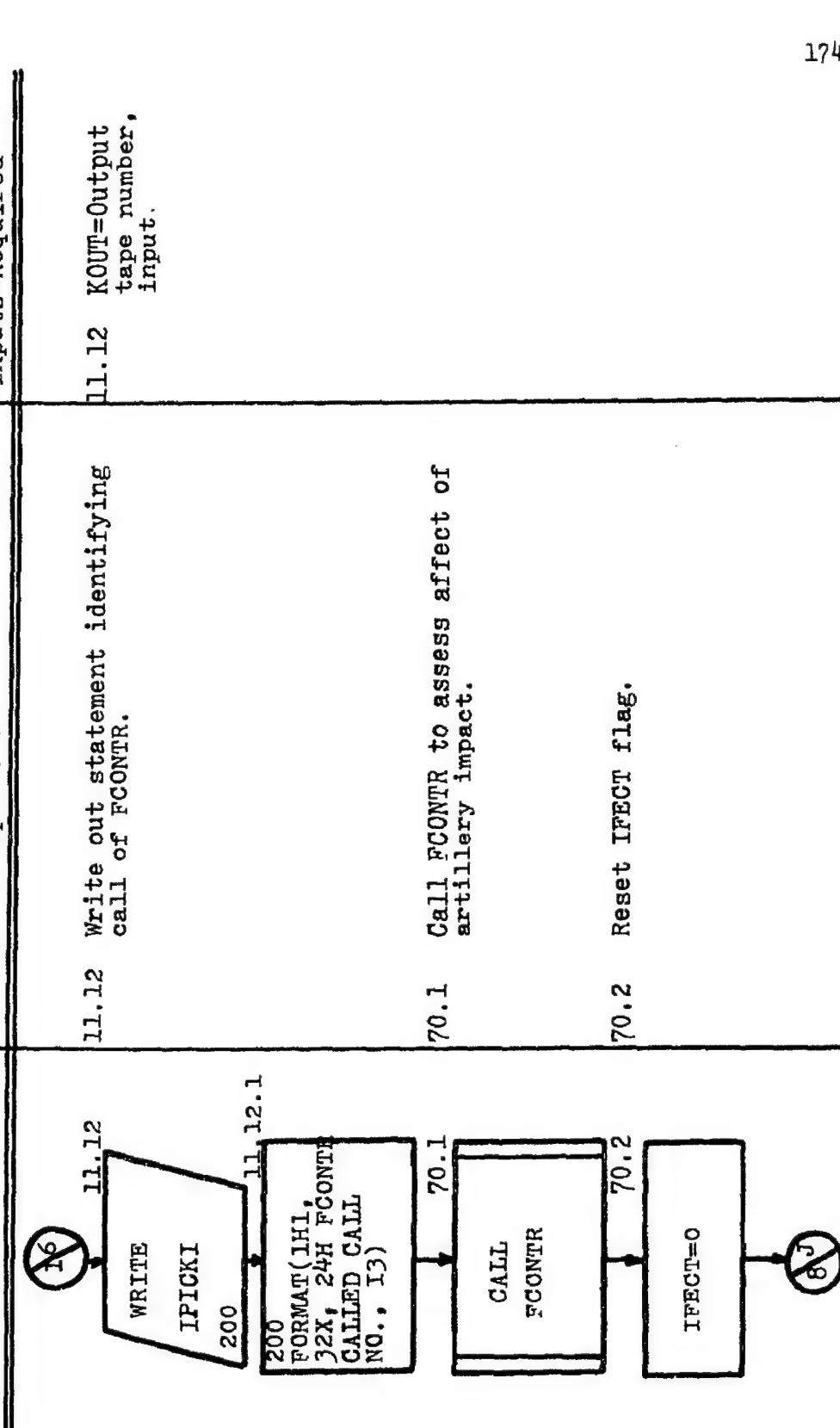
11.10 IPICKL=counter  
of calls to  
FCONTR

11.10 Index counter of calls to FCONTR

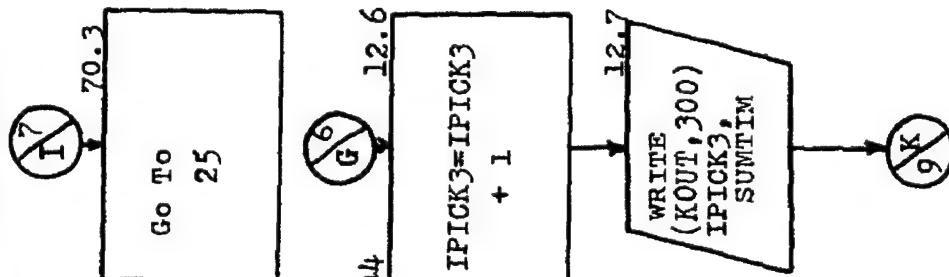
Page 7 of 21 Pages

Inputs Required

## Flow Chart



Flow Chart      Explanation



70.3      Return control to check for maximum battle time or continue processing element selected earlier.

12.6      Add one to counter.

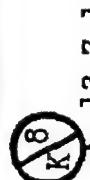
12.6      IPICK3=Counter of calls for Interim Summary.

12.7      Write out call for interim summary providing call number and time.

Flow Chart

Explanation

Page 9 of 21 Pages  
Inputs Required



12.7.1  
300  
FORMAT(1H0,32H  
INTSUM CALLED.  
CALL NO..I3.  
8H  
TIME=, F10.4

45      12.8      CALL  
          INTSUM

12.9  
SUMTIM =  
SUMTIM +  
TIME

12.10  
Go To  
25

12.8 Call subroutine INTSUM to prepare  
and print interim summary.

12.9 Increase summary time by a pre-  
scribed time interval.

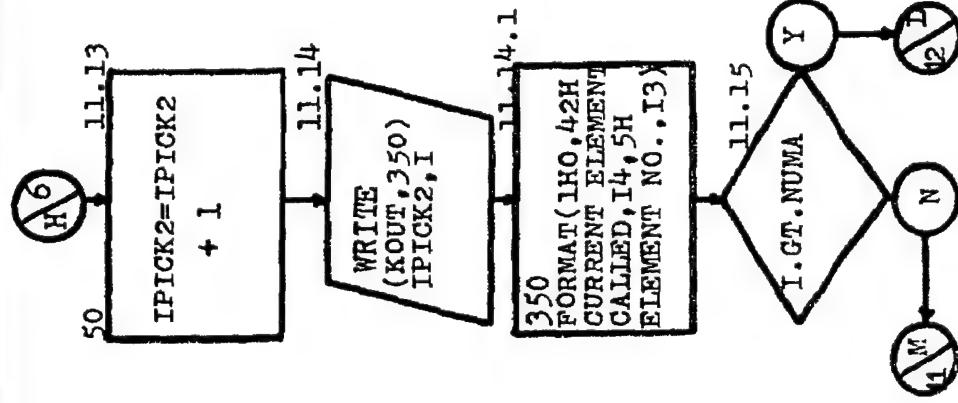
12.9      TIMINT=prescribed  
interval between  
time incremented  
summaries. Input.

12.10 Return control to statement num-  
ber 25 to continue processing  
element selected.

Flow Chart

Explanation

Page 10 of 21 Pages  
Inputs Required.



11.13 Increment counter.  
11.13 IPICK2=Counter  
of calls for  
normal process-  
ing of current  
element.

11.14 Write call for current element  
processing and identify element.

11.14.1

350  
FORMAT(1H0,4.2H  
CURRENT ELEMENT  
CALLED,14.5H  
ELEMENT NO.,I3)

11.15 Determine if current element is  
on side A or B.

11.15 NUMA=total number  
of elements on side  
A.  
This assumes  
that A elements  
are loaded first in  
numerical sequence.

**Flow Chart**

**Explanation**

Page 11 of 21 Pages  
Inputs Required



1004      31.2

Set limits for future use  
in do loops.

```
K=1
NW=1
NX=NUMA
NY=NUMA + 1
NZ=NUMA + NUMB
```

31.3

```
NW=1
NX=MUNA
NY=MUNA + 1
NZ=MUNA + MUNB
```

31.4

Go To 60

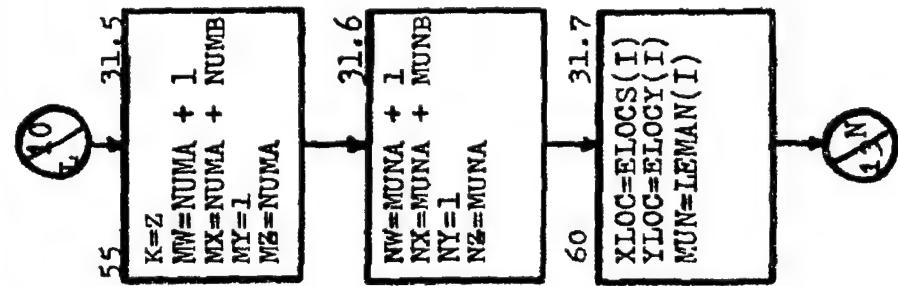
31.2      K=force indicator A=1, B=2.  
MW=First element for Side A.  
MX=Last element for Side A.  
MY=First element for Side B.  
MZ=Last element for Side B.  
NUMA=number of elements Side A.  
NUMB=number of elements Side B.  
Note - NUMA and NUMB are input.

31.3      NW=First maneuver Unit Side A.  
NX=Last maneuver Unit Side A.  
NY=First maneuver Unit Side B.  
NZ=Last maneuver Unit Side B.  
MUNA=Total number of maneuver units Side A.  
MUNB=Total number of maneuver units Side B.

Flow Chart

Explanation

Page 12 of 21 Pages  
Inputs Required



31.5 and .6 Same as 31.2 and .3 for Side A.  
31.5 and .6 Same as 31.2 and 31.3 for Side B.

31.7 Store X and Y location of current element. Store current elements maneuver unit.

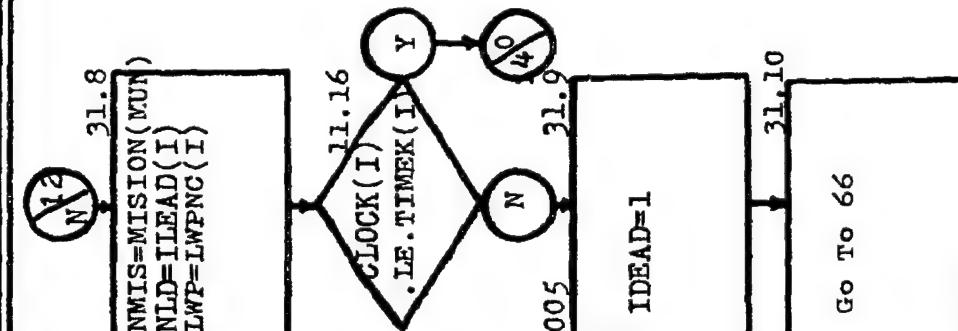
31.7 ELOCS(I)=X coordinate of element I,  
initially input.  
ELOCY(I)=Y coordinate of element I,  
initially input.  
LEMAN(I)=maneuver unit of element I.

Flow Chart

Explanation

Page 13 of 21 Pages

Inputs Required



31.8 Store mission of current element's maneuver unit.  
Store current element's leadership level.  
Store current element's weapon.

11.16 Check to see if current element is scheduled to die.

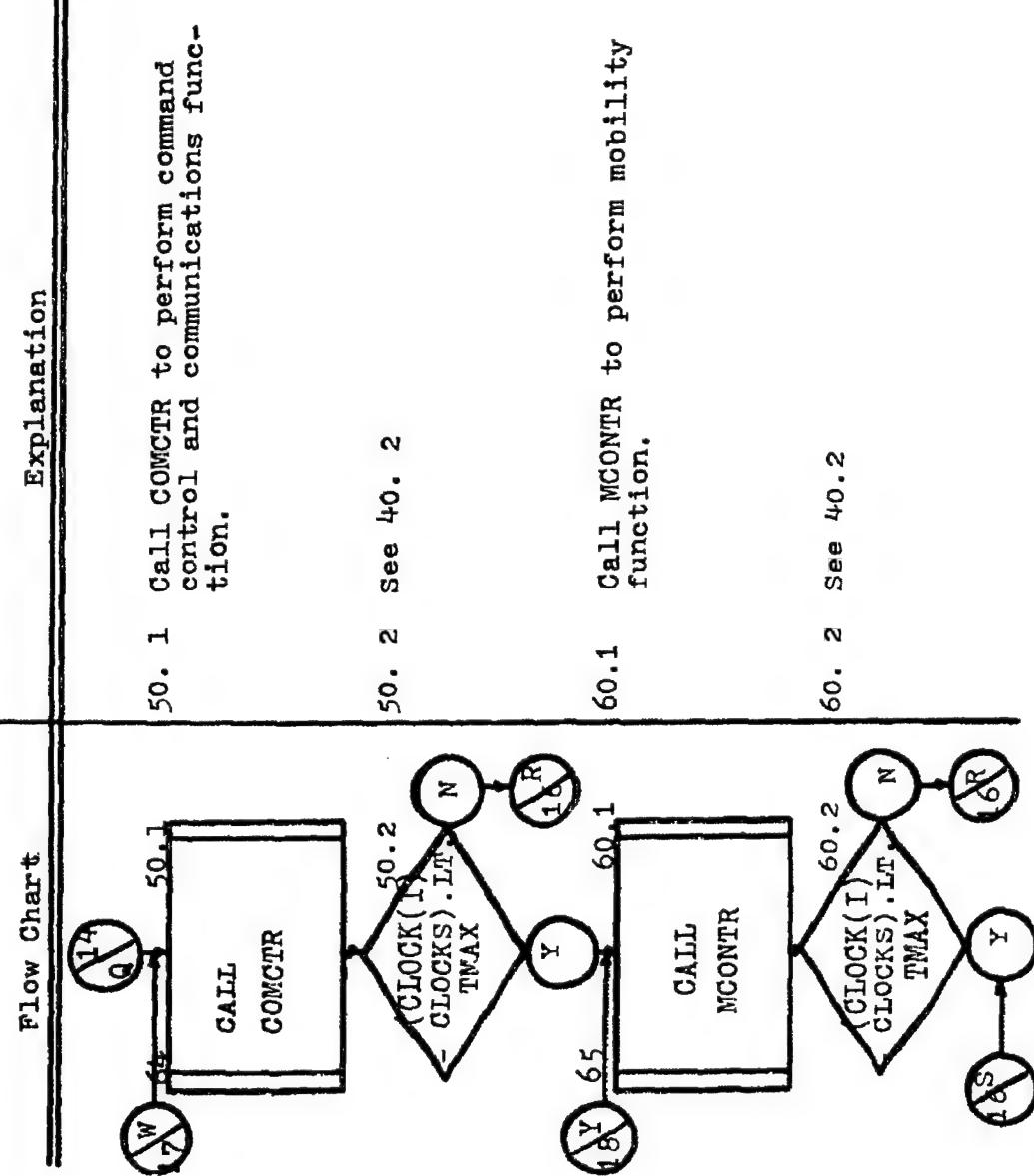
31.8 MISSION(MUN)=mission of maneuver unit input.  
ILEAD(I)=leadership level of element I input.  
LWPNC(I)=weapon assigned to current element - input.

11.16 TIMEK(I)=time at which element I is scheduled to die.  
Input at larger number and reset by casualty assessment.

Flow Chart	Explanation	Inputs Required
		<p>11.17 INTFLG(I)=is a flag set in any of the combat function subroutine's if an event is interrupted. It is initially set equal to zero.</p>
<pre> graph TD     62((62)) -- "INTFLG(I)" --&gt; D11_17{11.17}     D11_17 -- "0" --&gt; N11_17((N))     D11_17 -- "P" --&gt; Y11_17((Y))     Y11_17 --&gt; D40_1{40.1}     </pre>	<p>11.17 Check for interrupted event. If the current element had an event interrupted branch to identifying logic. If not, continue with normal processing.</p>	
<pre> graph TD     D40_1 -- "V" --&gt; D40_2{40.2}     D40_1 -- "Y" --&gt; Y40_1((Y))     D40_1 -- "P" --&gt; N40_1((N))     Y40_1 --&gt; D40_2     </pre>	<p>40.1 Call INTCTR to perform intelligence function.</p>	<p>40.1 Check to insure that activity length of current element does not exceed that permitted by the mode constraint. Note: This is a duplicate check as each subroutine must internally check for maximum permissible time length.</p>

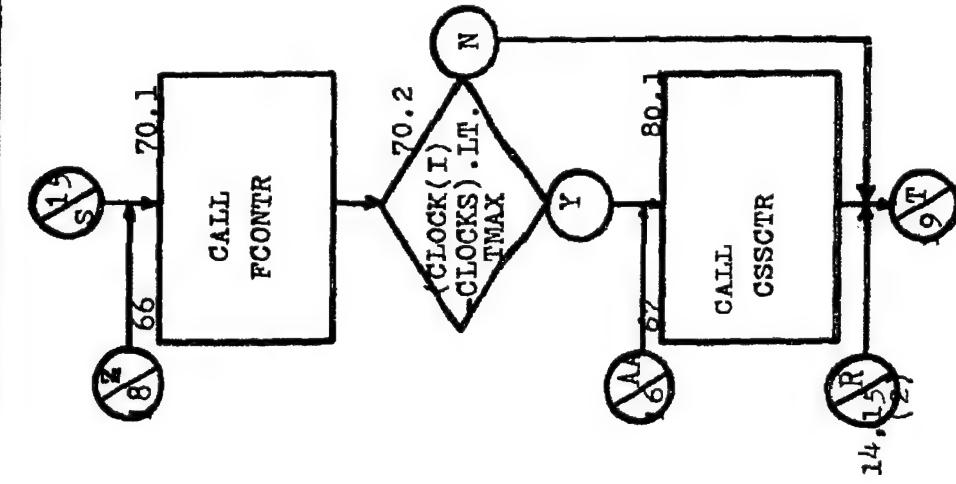
Page 15 of 21 Pages  
Inputs Required

## Explanation



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Inputs Required

Flow Chart      Explanation

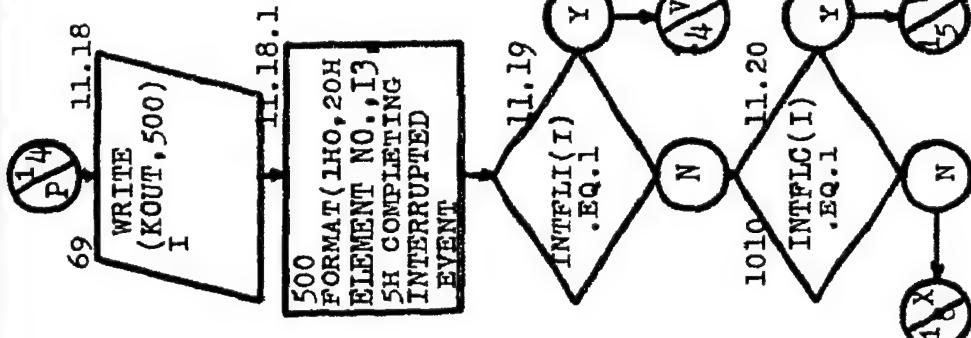


70.1 Call FCONTR to perform firepower function.

70.2 See 40.2

80.1 Call CSSCTR to perform combat service support function.

### Flow Chart



### Explanation

Page 17 of 21 Pages  
Inputs Required

Write statement that current element is attempting to complete an interrupted event.

13

**WRITE  
(KOUT,500)**

500  
FORMAT(1HO,20H  
ELEMENT NO.13,  
5H COMPLETING  
INTERRUPTED  
EVENT

ll.19 Check Interrupted intelligence flag.

11.19 INTFLI(I)=  
Interrupted  
Intelligence  
function flag -  
set in INTCTR.

11.20 Check interrupted command flag.

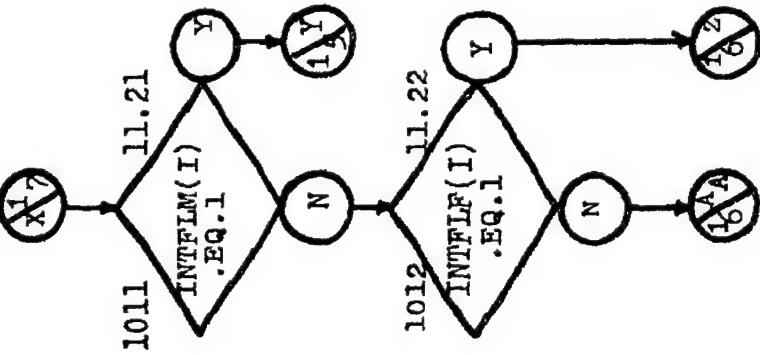
11.20 INTFLC(I)=  
Interrupted  
command control  
and communica-  
tions function.

11.20 INTFC(X) =

11.20 INTFLC(I)=  
Interrupted  
command control  
and communica-  
tions function.

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Inputs Required

Flow Chart      Explanation



11.21 Check interrupted mobility flag.

11.21 INTFLM(I)=  
Interrupted  
mobility func-  
tion flag -  
set in MCONTR.

11.22 Check interrupted Firepower flag.

11.22 INTFLF(I)=  
Interrupted fire-  
power function  
flag - set in  
FCONTR.

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Inputs Required

Flow Chart	Explanation
68	31.11 Compute the percentage of forces on Side A and B remaining.  RATA=RA/SA RATB=RB/SB
	31.11 RA=number of elements on Side A remaining-updated in casualty assessment.
	31.11 SA=Total number of elements Side A at beginning of simulation - input.
	31.11 RB=number of elements on Side B remaining-updated in casualty assessment.
	31.11 SB=Total number of elements Side B at beginning of simulation - input.
	12.11 Compare existing ratio to input criteria force A.
	12.11 RATE.LE. 12.11 RATEP(ISTEP_A) Y
	12.11 N
	12.12 Compare existing ratio to input criteria force B.
	12.12 RATEB.LE. 12.12 RATEPB(ISTEPB) Y
	12.12 N
	12.15 Return control to select the next element.
	12.15 Go To 5
	12.15 CCC

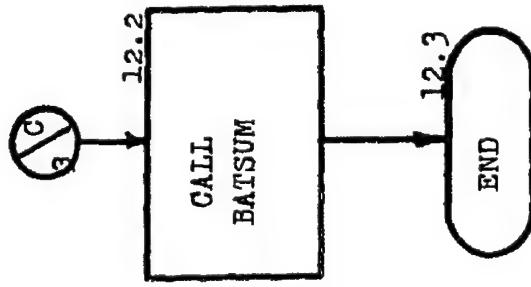
RATAP(ISTEPA)=  
Input criteria to describe points at which analysis is desired. These points are successively stepped in an input sequence on ISTEP which is increased each time the summary is presented.

Flow Chart	Explanation	
	Page 20 of 21 pages Inputs Required	
	Continued: 12.12 RATBP(1STEPB)= same as RATAP except for side B	

Page 21 of 21 Pages  
Inputs Required

Explanation

Flow Chart



12.2 Call Batsum to print the summary  
of the battle at the end of a

Figure B-2

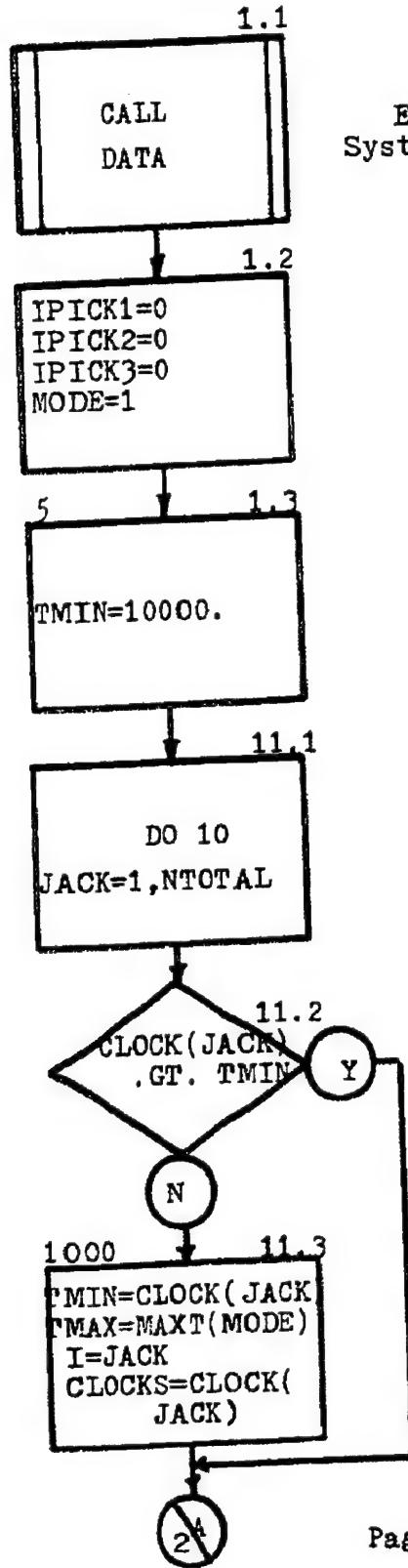
Executive Routine  
System Flow Chart

Figure B-2 (continued)

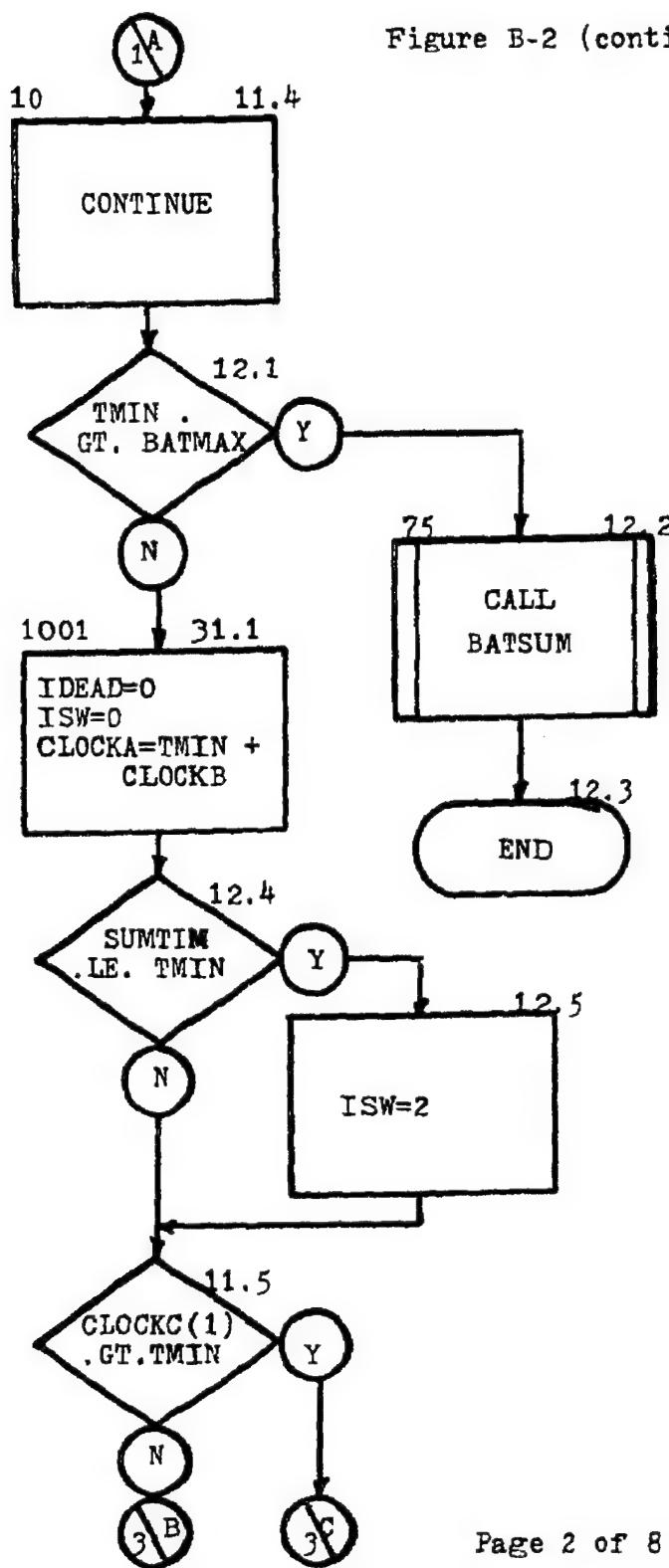
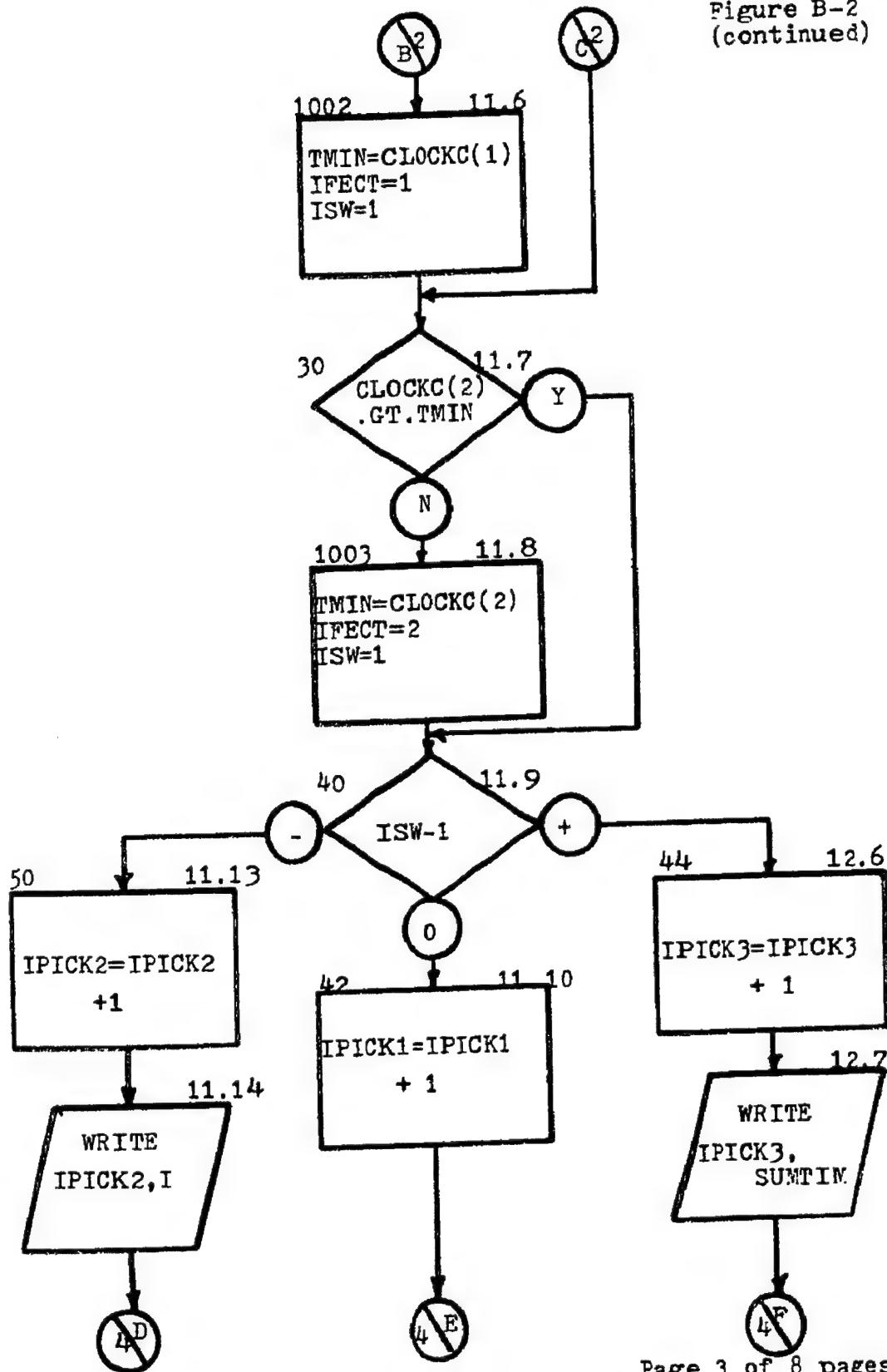


Figure B-2  
(continued)

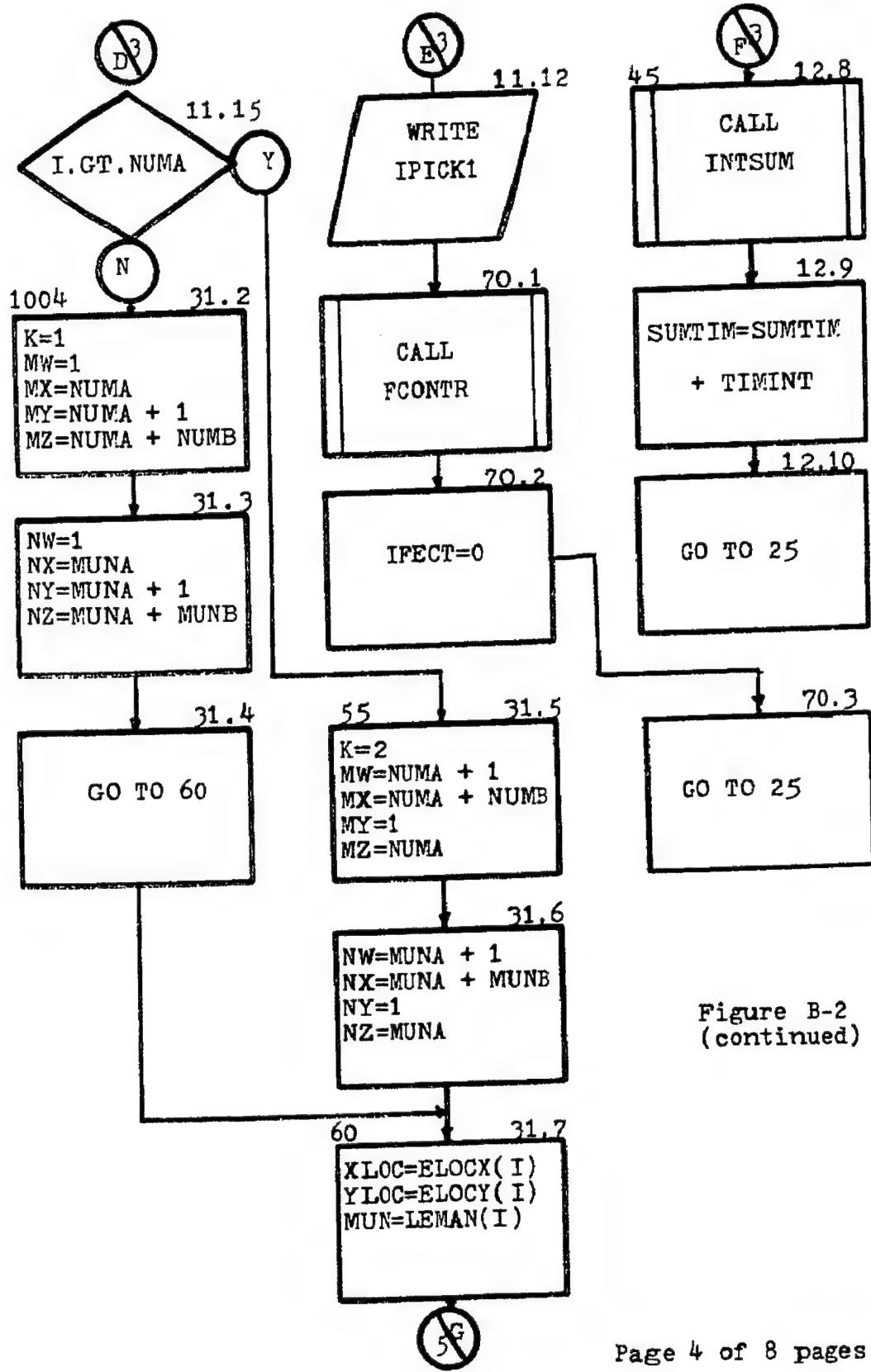
Figure B-2  
(continued)

Figure B-2 (continued)

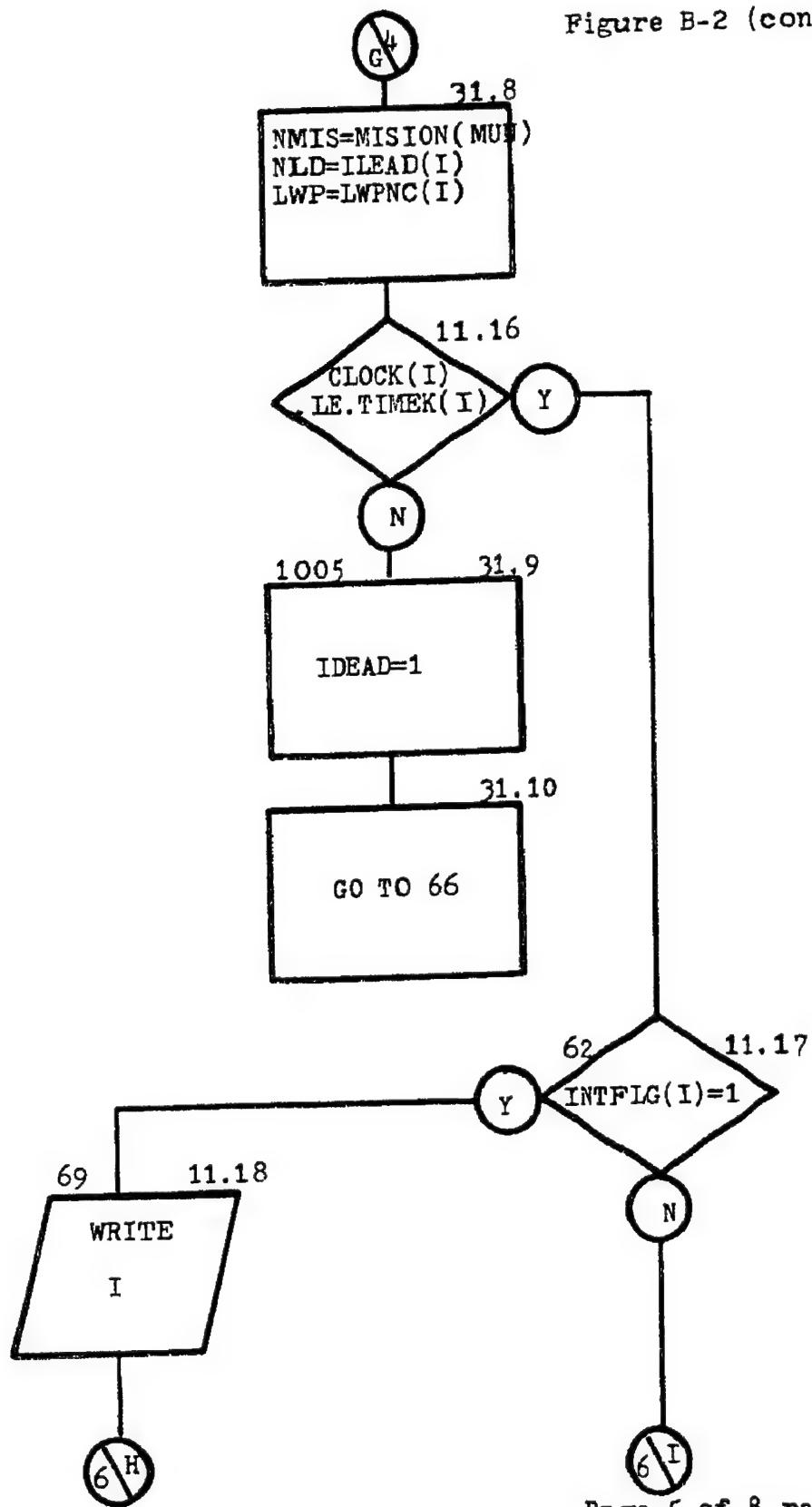
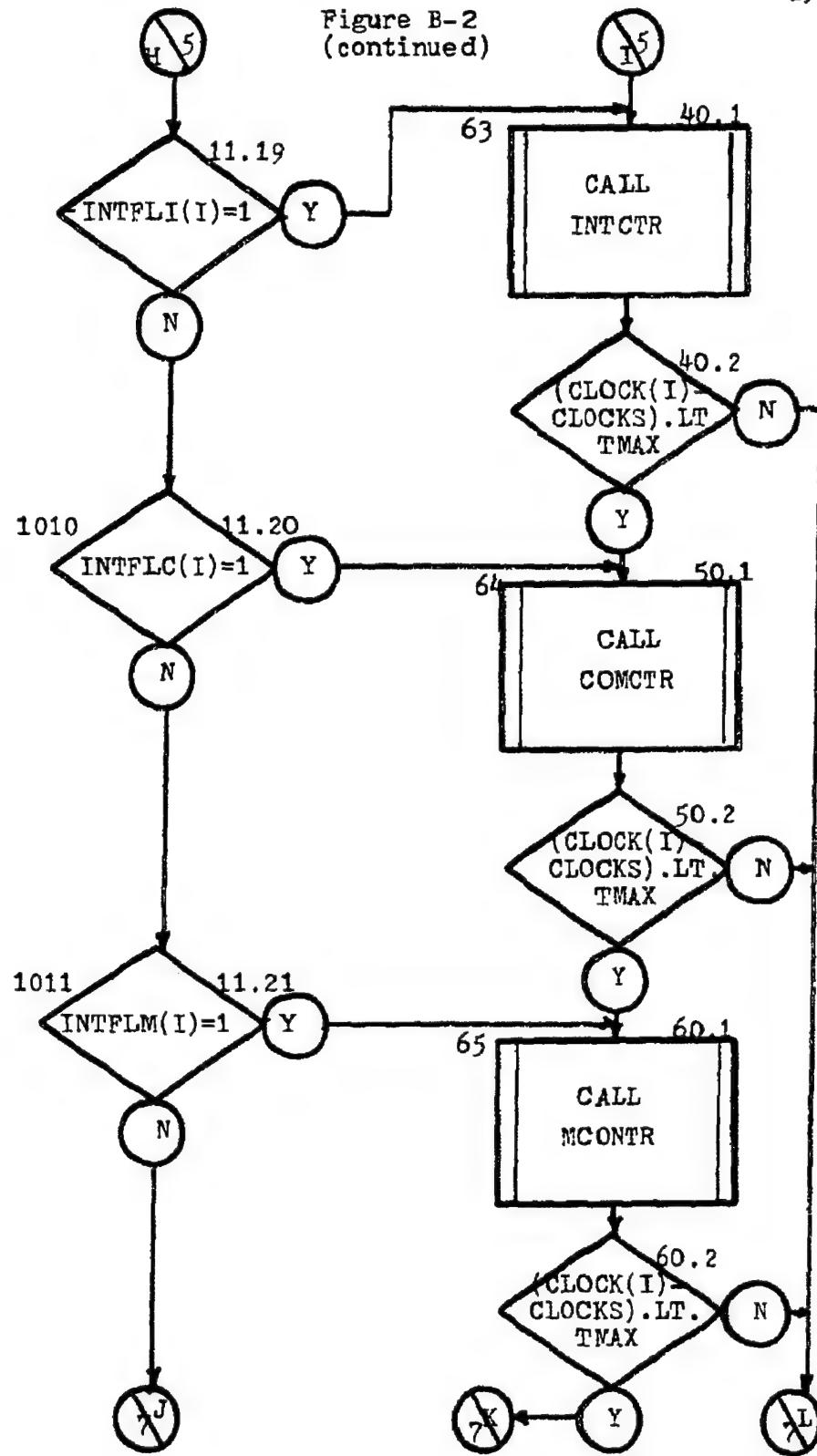


Figure B-2  
(continued)

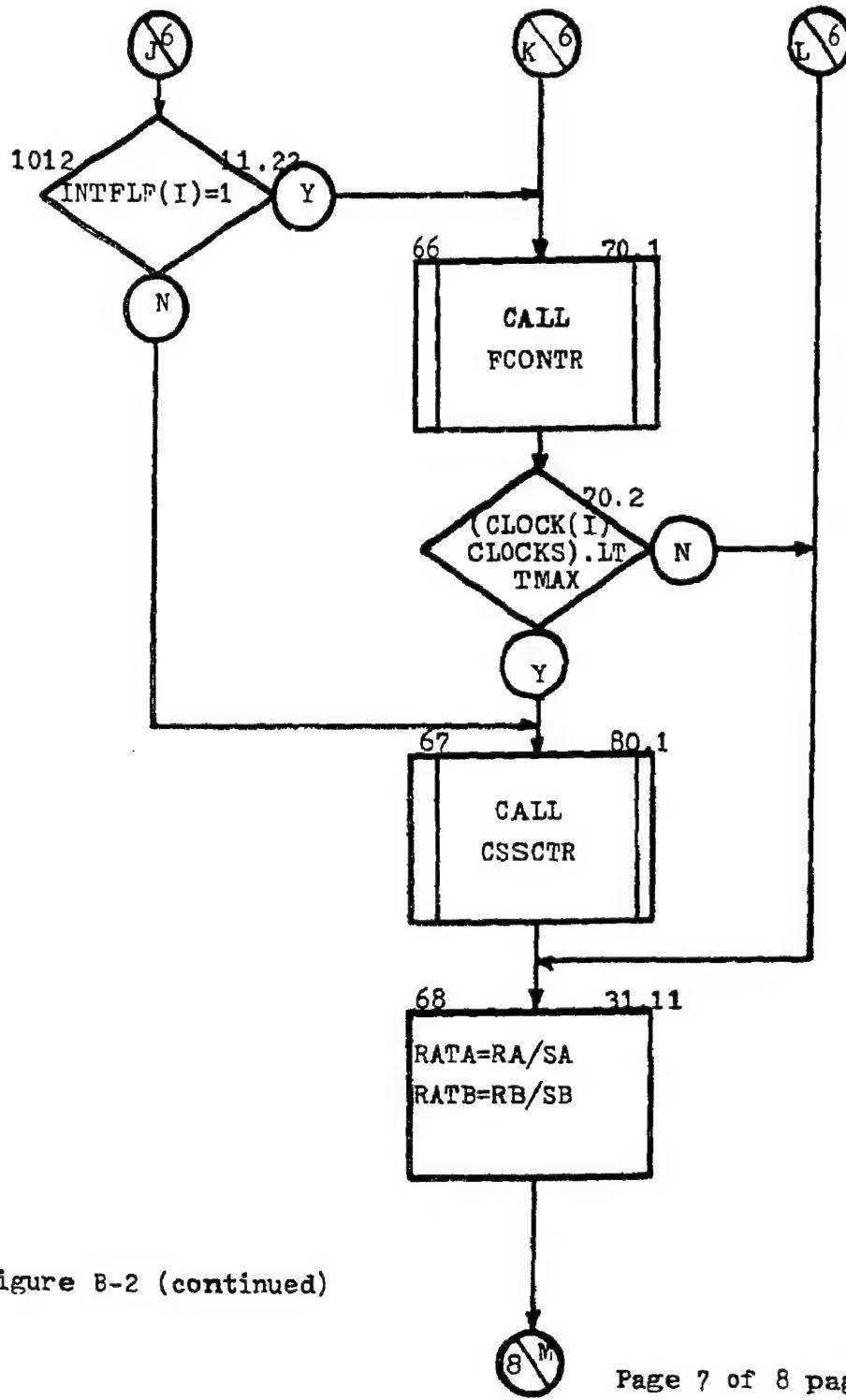
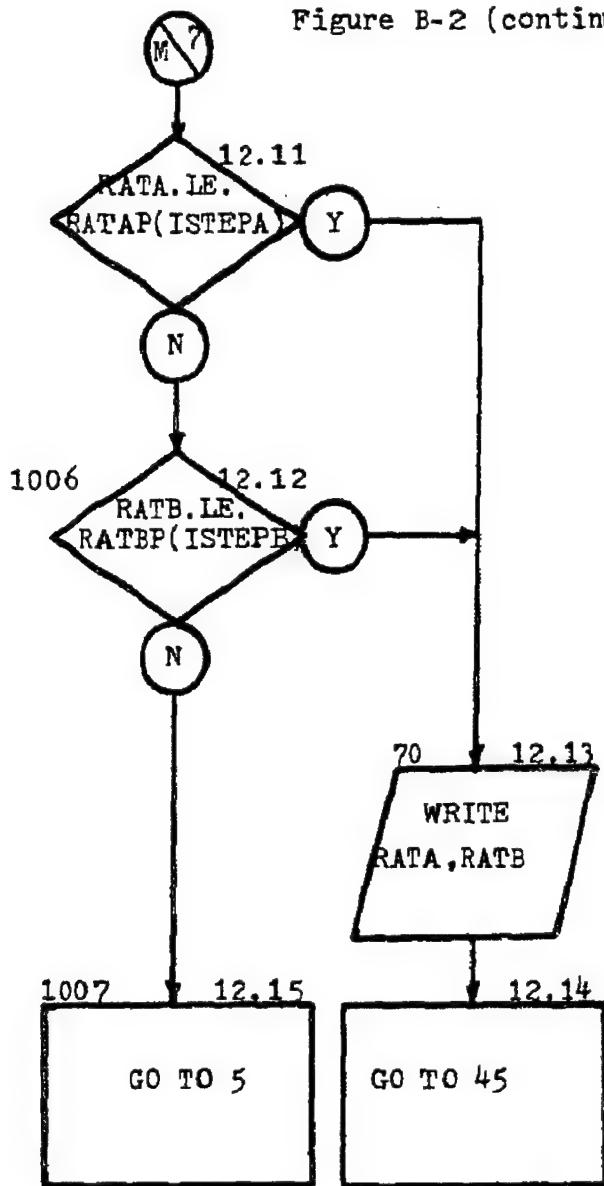


Figure B-2 (continued)

Figure B-2 (continued)



1. گروه اول (G1) میانگین ۰.۷۹ کیلوگرم و وزن ۲۲۵ گرم داشتند.  
 ۲. گروه دوم (G2) میانگین ۰.۸۱ کیلوگرم و وزن ۲۳۰ گرم داشتند.  
 ۳. گروه سوم (G3) میانگین ۰.۸۴ کیلوگرم و وزن ۲۳۵ گرم داشتند.  
 ۴. گروه چهارم (G4) میانگین ۰.۸۶ کیلوگرم و وزن ۲۴۰ گرم داشتند.  
 ۵. گروه پنجم (G5) میانگین ۰.۸۷ کیلوگرم و وزن ۲۴۱ گرم داشتند.  
 ۶. گروه ششم (G6) میانگین ۰.۸۸ کیلوگرم و وزن ۲۴۲ گرم داشتند.  
 ۷. گروه هفتم (G7) میانگین ۰.۸۹ کیلوگرم و وزن ۲۴۳ گرم داشتند.  
 ۸. گروه هشتم (G8) میانگین ۰.۹۰ کیلوگرم و وزن ۲۴۴ گرم داشتند.  
 ۹. گروه نهم (G9) میانگین ۰.۹۱ کیلوگرم و وزن ۲۴۵ گرم داشتند.  
 ۱۰. گروه دهم (G10) میانگین ۰.۹۲ کیلوگرم و وزن ۲۴۶ گرم داشتند.



THIS STATEMENT IS A NON-NEGOTIABLE STATEMENT.

1. AGENCIES  
- CARRY NO LIABILITY UNLESS  
- LIABILITIES ARE PROVED.

2. PAYMENT  
/ JULY 14 1977

3. DATED  
12/24/79  
PAW.





202

Precious Metal Content 73/70  $\bar{v}^{P7}=1$

Fig. 41.

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STATIONEN, LATELS

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Population	Length	Flight	Distance	Number	Species
1000	100	100	100	10	<i>Phalaropus tricolor</i>
1000	100	100	100	10	<i>Phalaropus tricolor</i>
1000	100	100	100	10	<i>Phalaropus tricolor</i>

PROJECT	Length	3243
Surfex	1074	1674
Surfex	1074	3152
Surfex	1074	3152
Surfex	1074	3152

PROJECT	Length	3243
Surfex	1074	1674
Surfex	1074	3152
Surfex	1074	3152
Surfex	1074	3152

۷۰۰ میلیون دلار را در سال ۱۹۸۷ میلادی در ساخت

FT: 44-443-7

卷之二

6

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VARIABLES	SN	TYPE	REGULATION
2405	2413	NEAL	/ /
2403	2413a	NEAL	/ /
2473	74	NEAL	/ /
2414	24	NEAL	/ /
2472	2417	NEAL	/ /
2470	2417a	NEAL	/ /
2477	2418	NEAL	/ /
6271	2418a	NEAL	/ /
6272	2418	NEAL	/ /
6273	2419	NEAL	/ /
6274	2419a	NEAL	/ /
6275	2420	NEAL	/ /
6276	2420a	NEAL	/ /
6277	2421	NEAL	/ /
6278	2421a	NEAL	/ /
6279	2422	NEAL	/ /
6280	2422a	NEAL	/ /
6281	2423	NEAL	/ /
6282	2423a	NEAL	/ /
6283	2424	NEAL	/ /
6284	2424a	NEAL	/ /
6285	2425	NEAL	/ /
6286	2425a	NEAL	/ /
6287	2426	NEAL	/ /
6288	2426a	NEAL	/ /
6289	2427	NEAL	/ /
6290	2427a	NEAL	/ /
6291	2428	NEAL	/ /
6292	2428a	NEAL	/ /
6293	2429	NEAL	/ /
6294	2429a	NEAL	/ /
6295	2430	NEAL	/ /
6296	2430a	NEAL	/ /
6297	2431	NEAL	/ /
6298	2431a	NEAL	/ /
6299	2432	NEAL	/ /
6300	2432a	NEAL	/ /
6291	2433	NEAL	/ /
6292	2433a	NEAL	/ /
6293	2434	NEAL	/ /
6294	2434a	NEAL	/ /
6295	2435	NEAL	/ /
6296	2435a	NEAL	/ /
6297	2436	NEAL	/ /
6298	2436a	NEAL	/ /
6299	2437	NEAL	/ /
6300	2437a	NEAL	/ /
6291	2438	NEAL	/ /
6292	2438a	NEAL	/ /
6293	2439	NEAL	/ /
6294	2439a	NEAL	/ /
6295	2440	NEAL	/ /
6296	2440a	NEAL	/ /
6297	2441	NEAL	/ /
6298	2441a	NEAL	/ /
6299	2442	NEAL	/ /
6300	2442a	NEAL	/ /

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$\{f_1\} \rightarrow \{f_2\}$   $\{f_3\} \rightarrow \{f_4\}$   $\{f_5\} \rightarrow \{f_6\}$

it. FJ-MAL(0,3,3-70) ADDITIONALLY CONTROLS A ELEMENT OF ELEMENT N, 10)  
SLOC(1) = SLOC(K(1)) + 10.  
END





• 3 / 4 •  $\omega^2 = 2$

نامه از  
فیلم ۴۰ + ۵.۷

F11-40 +15.7 62/24.7 12+22.5w 17.6w 14

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卷之三

卷之三

卷之二

وَلِلْمُؤْمِنِينَ أَنْ يَرْجِعُوا إِلَىٰ مَا  
كَانُوا يَفْسَدُونَ وَلَا يُنْهَا  
أَنْ يَرْجِعُوا إِلَىٰ مَا كَانُوا  
يَفْسَدُونَ وَلَا يُنْهَا  
أَنْ يَرْجِعُوا إِلَىٰ مَا كَانُوا  
يَفْسَدُونَ وَلَا يُنْهَا

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	ROUTINE CALL	SYN	TYPE	ROUTINE CALL	SYN	TYPE
2472	2474	CALL	CALL	2474	2475	CALL
2475	2473	CALL	CALL	2475	2476	CALL
2476	2473	CALL	CALL	2476	2477	CALL
2477	2478	CALL	CALL	2477	2478	CALL
2478	2479	CALL	CALL	2478	2479	CALL
2479	2472	CALL	CALL	2479	2480	CALL
2480	2478	CALL	CALL	2480	2481	CALL
2481	2477	CALL	CALL	2481	2482	CALL
2482	2474	CALL	CALL	2482	2483	CALL
2483	2474	CALL	CALL	2483	2484	CALL
2484	2474	CALL	CALL	2484	2485	CALL
2485	2474	CALL	CALL	2485	2486	CALL
2486	2474	CALL	CALL	2486	2487	CALL
2487	2474	CALL	CALL	2487	2488	CALL
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2500	2474	CALL	CALL	2500	2501	CALL
2501	2474	CALL	CALL	2501	2502	CALL
2502	2474	CALL	CALL	2502	2503	CALL
2503	2474	CALL	CALL	2503	2504	CALL
2504	2474	CALL	CALL	2504	2505	CALL
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2506	2474	CALL	CALL	2506	2507	CALL
2507	2474	CALL	CALL	2507	2508	CALL
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13. PRELIMINARY SURVEY OF THE CLOUDS AND SUMMARY OF THE ELEMENTS OF THE CLOUDS FOR THE MONTH OF APRIL.

三





FIN 70 47-517 44624170 220220200 145

卷之三

Chlorophytum comosum (L.) Willd., Clusiaceae (1), Canna (1), Cyperaceae (1), Euphorbiaceae (1), Malpighiaceae (1), Melastomaceae (1), Myrsinaceae (1), Piperaceae (1), Rosaceae (1), Rubiaceae (1), Solanaceae (1), Tiliaceae (1), Urticaceae (1).

卷之三

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FIN 40 45:7 44/2417.4 22.22.22-9 14.52









SEARCHED  SERIALIZED  INDEXED  FILED

RECORDED

16 SEP 1966 DEPARTMENT OF  
DEFENSE  
DCB

115





LURE #	LURE #	INDEX	INDEX	FROM-TO	LENGTH	POPULATION	
						INSTOCK	INSTOCK
514	217	FMT	144*	113	113	0	0
271	111	FMT	63	22			
554	101	FMT	54	3			
512	202	FMT	37	36			
376	103	FMT	12	42			
423	104	FMT	12	57			
432	105	FMT	12	58			
441	205	FMT	12	58			
474	107	FMT	12	58			
565	207	FMT	12	58			
255	208	FMT	12	71			
307	211	FMT	12	71			
276	211	FMT	91	66			
617	312	FMT	103	405			
614	313	FMT	103	405			
613	316						
7	11						
71	111						
62	112						
420	113	*	1				
142	114	*	1				
117	115	*	1				
117	116	*	1				
117	118	*	1				
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210	392	*	1				
210	393	*	1				
210	394	*	1				
210	395	*	1				
210	396	*	1				
210	397	*	1				
210	398	*	1				
210	399	*	1				
210	400	*	1				
210	401	*	1				
210	402	*	1				
210	403	*	1				
210	404	*	1				
210	405	*	1				
210	406	*	1				
210	407	*	1				
210	408	*	1				
210	409	*	1				
210	410	*	1				
210	411	*	1				
210	412	*	1				
210	413	*	1				
210	414	*	1				
210	415	*	1				
210	416	*	1				
210	417	*	1				
210	418	*	1				
210	419	*	1				
210	420	*	1				
210	421	*	1				
210	422	*	1				
210	423	*	1				
210	424	*	1				
210	425	*	1				
210	426	*	1				

12.22.47- 62.24.7- 45 45

THE LINES  
LINEAR AUGMENT - CANEX

3.7 5 4.5-5 4.5-5 4.5-5 4.5-5

NO. T-3E HONES 25

45

NO. T-3E HONES 25

45

TABLE OUTLINES

LINEAR	AUGMENT	LEADER	FILE	LINEAR	AUGMENT	LEADER	FILE
25.2	2.4	442.	660	25.2	2.4	442.	660
25.3	2.5	443.	661	25.2	2.4	442.	661
25.4	2.4	444.	662	25.2	2.4	442.	662
25.5	2.5	445.	663	25.2	2.4	442.	663
25.6	2.6	446.	664	25.2	2.4	442.	664
25.7	2.7	447.	665	25.2	2.4	442.	665
25.8	2.8	448.	666	25.2	2.4	442.	666
25.9	2.9	449.	667	25.2	2.4	442.	667
25.10	2.10	450.	668	25.2	2.4	442.	668
25.11	2.11	451.	669	25.2	2.4	442.	669
25.12	2.12	452.	670	25.2	2.4	442.	670
25.13	2.13	453.	671	25.2	2.4	442.	671
25.14	2.14	454.	672	25.2	2.4	442.	672
25.15	2.15	455.	673	25.2	2.4	442.	673
25.16	2.16	456.	674	25.2	2.4	442.	674
25.17	2.17	457.	675	25.2	2.4	442.	675
25.18	2.18	458.	676	25.2	2.4	442.	676
25.19	2.19	459.	677	25.2	2.4	442.	677
25.20	2.20	460.	678	25.2	2.4	442.	678
25.21	2.21	461.	679	25.2	2.4	442.	679
25.22	2.22	462.	680	25.2	2.4	442.	680
25.23	2.23	463.	681	25.2	2.4	442.	681
25.24	2.24	464.	682	25.2	2.4	442.	682
25.25	2.25	465.	683	25.2	2.4	442.	683
25.26	2.26	466.	684	25.2	2.4	442.	684
25.27	2.27	467.	685	25.2	2.4	442.	685
25.28	2.28	468.	686	25.2	2.4	442.	686
25.29	2.29	469.	687	25.2	2.4	442.	687
25.30	2.30	470.	688	25.2	2.4	442.	688
25.31	2.31	471.	689	25.2	2.4	442.	689
25.32	2.32	472.	690	25.2	2.4	442.	690
25.33	2.33	473.	691	25.2	2.4	442.	691
25.34	2.34	474.	692	25.2	2.4	442.	692
25.35	2.35	475.	693	25.2	2.4	442.	693
25.36	2.36	476.	694	25.2	2.4	442.	694
25.37	2.37	477.	695	25.2	2.4	442.	695
25.38	2.38	478.	696	25.2	2.4	442.	696
25.39	2.39	479.	697	25.2	2.4	442.	697
25.40	2.40	480.	698	25.2	2.4	442.	698
25.41	2.41	481.	699	25.2	2.4	442.	699
25.42	2.42	482.	700	25.2	2.4	442.	700
25.43	2.43	483.	701	25.2	2.4	442.	701
25.44	2.44	484.	702	25.2	2.4	442.	702
25.45	2.45	485.	703	25.2	2.4	442.	703
25.46	2.46	486.	704	25.2	2.4	442.	704
25.47	2.47	487.	705	25.2	2.4	442.	705
25.48	2.48	488.	706	25.2	2.4	442.	706
25.49	2.49	489.	707	25.2	2.4	442.	707
25.50	2.50	490.	708	25.2	2.4	442.	708
25.51	2.51	491.	709	25.2	2.4	442.	709
25.52	2.52	492.	710	25.2	2.4	442.	710
25.53	2.53	493.	711	25.2	2.4	442.	711
25.54	2.54	494.	712	25.2	2.4	442.	712
25.55	2.55	495.	713	25.2	2.4	442.	713
25.56	2.56	496.	714	25.2	2.4	442.	714
25.57	2.57	497.	715	25.2	2.4	442.	715
25.58	2.58	498.	716	25.2	2.4	442.	716
25.59	2.59	499.	717	25.2	2.4	442.	717
25.60	2.60	500.	718	25.2	2.4	442.	718
25.61	2.61	501.	719	25.2	2.4	442.	719
25.62	2.62	502.	720	25.2	2.4	442.	720
25.63	2.63	503.	721	25.2	2.4	442.	721
25.64	2.64	504.	722	25.2	2.4	442.	722
25.65	2.65	505.	723	25.2	2.4	442.	723
25.66	2.66	506.	724	25.2	2.4	442.	724
25.67	2.67	507.	725	25.2	2.4	442.	725
25.68	2.68	508.	726	25.2	2.4	442.	726
25.69	2.69	509.	727	25.2	2.4	442.	727
25.70	2.70	510.	728	25.2	2.4	442.	728
25.71	2.71	511.	729	25.2	2.4	442.	729
25.72	2.72	512.	730	25.2	2.4	442.	730
25.73	2.73	513.	731	25.2	2.4	442.	731
25.74	2.74	514.	732	25.2	2.4	442.	732
25.75	2.75	515.	733	25.2	2.4	442.	733
25.76	2.76	516.	734	25.2	2.4	442.	734
25.77	2.77	517.	735	25.2	2.4	442.	735
25.78	2.78	518.	736	25.2	2.4	442.	736
25.79	2.79	519.	737	25.2	2.4	442.	737
25.80	2.80	520.	738	25.2	2.4	442.	738
25.81	2.81	521.	739	25.2	2.4	442.	739
25.82	2.82	522.	740	25.2	2.4	442.	740
25.83	2.83	523.	741	25.2	2.4	442.	741
25.84	2.84	524.	742	25.2	2.4	442.	742
25.85	2.85	525.	743	25.2	2.4	442.	743
25.86	2.86	526.	744	25.2	2.4	442.	744
25.87	2.87	527.	745	25.2	2.4	442.	745
25.88	2.88	528.	746	25.2	2.4	442.	746
25.89	2.89	529.	747	25.2	2.4	442.	747
25.90	2.90	530.	748	25.2	2.4	442.	748
25.91	2.91	531.	749	25.2	2.4	442.	749
25.92	2.92	532.	750	25.2	2.4	442.	750
25.93	2.93	533.	751	25.2	2.4	442.	751
25.94	2.94	534.	752	25.2	2.4	442.	752
25.95	2.95	535.	753	25.2	2.4	442.	753
25.96	2.96	536.	754	25.2	2.4	442.	754
25.97	2.97	537.	755	25.2	2.4	442.	755
25.98	2.98	538.	756	25.2	2.4	442.	756
25.99	2.99	539.	757	25.2	2.4	442.	757
25.100	2.100	540.	758	25.2	2.4	442.	758
25.101	2.101	541.	759	25.2	2.4	442.	759
25.102	2.102	542.	760	25.2	2.4	442.	760
25.103	2.103	543.	761	25.2	2.4	442.	761
25.104	2.104	544.	762	25.2	2.4	442.	762
25.105	2.105	545.	763	25.2	2.4	442.	763
25.106	2.106	546.	764	25.2	2.4	442.	764
25.107	2.107	547.	765	25.2	2.4	442.	765
25.108	2.108	548.	766	25.2	2.4	442.	766
25.109	2.109	549.	767	25.2	2.4	442.	767
25.110	2.110	550.	768	25.2	2.4	442.	768
25.111	2.111	551.	769	25.2	2.4	442.	769
25.112	2.112	552.	770	25.2	2.4	442.	770
25.113	2.113	553.	771	25.2	2.4	442.	771
25.114	2.114	554.	772	25.2	2.4	442.	772
25.115	2.115	555.	773	25.2	2.4	442.	773
25.116	2.116	556.	774	25.2	2.4	442.	774
25.117	2.117	557.	775	25.2	2.4	442.	775
25.118	2.118	558.	776	25.2	2.4	442.	776
25.119	2.119	559.	777	25.2	2.4	442.	777
25.120	2.120	560.	778	25.2	2.4	442.	778
25.121	2.121	561.	779	25.2	2.4	442.	779
25.122	2.122	562.	780	25.2	2.4	442.	780
25.123	2.123	563.	781	25.2	2.4	442.	781
25.124	2.124	564.	782	25.2	2.4	442.	782
25.125	2.125	565.	783	25.2	2.4	442.	783
25.126	2.126	566.	784	25.2	2.4	442.	784
25.127	2.127	567.	785	25.2	2.4	442.	785
25.128	2.128	568.	786	25.2	2.4	442.	786
25.129	2.129	569.	787	25.2	2.4	442.	787
25.130	2.130	570.	788	25.2	2.4	442.	788
25.131	2.131	571.	789	25.2	2.4	442.	789
25.132	2.132	572.	790	25.2	2.4	442.	790
25.133	2.133	573.	791	25.2	2.4	442.	791
25.134	2.134	574.	792	25.2	2.4	442.	792
25.135	2.135	575.	793	25.2	2.4	442.	793
25.136	2.136	576.	794	25.2	2.4	442.	794
25.137	2.137	577.	795	25.2	2.4	442.	795
25.138	2.138	578.	796	25.2	2.4	442.	796
25.139	2.139	579.	797	25.2	2.4	442.	797
25.140	2.140	580.	798	25.2	2.4	442.	798
25.141	2.141	581.	799	25.2	2.4	442.	799
25.142	2.142	582.	800	25.2	2.4	442.	800
25.143	2.143	583.	801	25.2	2.4	442.	801
25.144	2.144	584.	802	25.2	2.4	442.	802
25.145	2.145	585.	803	25.2	2.4	442.	803
25.146	2.146	586.	804	25.2	2.4	442.	804
25.147	2.147	587.	805	25.2	2.4	442.	805
25.148	2.148	588.	806	25.2	2.4	442.	806
25.149	2.149	589.	80				



THE PRACTICAL HANDBOOK OF  
ELECTRICAL ENGINEERING AND  
TELEGRAPHY FOR STUDENTS.

BY  
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THE PRACTICAL HANDBOOK OF  
ELECTRICAL ENGINEERING AND  
TELEGRAPHY FOR STUDENTS.

2

2

TENSILE STRENGTH	DUCTILITY	CONDUCTIVITY	TOTAL NUMBER OF CLOTHESPIN SIZES								
			1	2	3	4	5	6	7	8	9
1000 lbs.	100%	100%	1	2	3	4	5	6	7	8	9
900	90	90	1	2	3	4	5	6	7	8	9
800	80	80	1	2	3	4	5	6	7	8	9
700	70	70	1	2	3	4	5	6	7	8	9
600	60	60	1	2	3	4	5	6	7	8	9
500	50	50	1	2	3	4	5	6	7	8	9
400	40	40	1	2	3	4	5	6	7	8	9
300	30	30	1	2	3	4	5	6	7	8	9
200	20	20	1	2	3	4	5	6	7	8	9
100	10	10	1	2	3	4	5	6	7	8	9
50	5	5	1	2	3	4	5	6	7	8	9
25	2.5	2.5	1	2	3	4	5	6	7	8	9
12.5	1.25	1.25	1	2	3	4	5	6	7	8	9
6.25	0.625	0.625	1	2	3	4	5	6	7	8	9
3.125	0.3125	0.3125	1	2	3	4	5	6	7	8	9
1.5625	0.15625	0.15625	1	2	3	4	5	6	7	8	9
0.78125	0.078125	0.078125	1	2	3	4	5	6	7	8	9
0.390625	0.0390625	0.0390625	1	2	3	4	5	6	7	8	9
0.1953125	0.01953125	0.01953125	1	2	3	4	5	6	7	8	9
0.09765625	0.009765625	0.009765625	1	2	3	4	5	6	7	8	9
0.048828125	0.0048828125	0.0048828125	1	2	3	4	5	6	7	8	9
0.0244140625	0.00244140625	0.00244140625	1	2	3	4	5	6	7	8	9
0.01220703125	0.001220703125	0.001220703125	1	2	3	4	5	6	7	8	9
0.006103515625	0.0006103515625	0.0006103515625	1	2	3	4	5	6	7	8	9
0.0030517578125	0.00030517578125	0.00030517578125	1	2	3	4	5	6	7	8	9
0.00152587890625	0.000152587890625	0.000152587890625	1	2	3	4	5	6	7	8	9
0.000762939453125	0.0000762939453125	0.0000762939453125	1	2	3	4	5	6	7	8	9
0.0003814697265625	0.00003814697265625	0.00003814697265625	1	2	3	4	5	6	7	8	9
0.00019073486328125	0.000019073486328125	0.000019073486328125	1	2	3	4	5	6	7	8	9
0.000095367431640625	0.0000095367431640625	0.0000095367431640625	1	2	3	4	5	6	7	8	9
0.0000476837158203125	0.00000476837158203125	0.00000476837158203125	1	2	3	4	5	6	7	8	9
0.00002384185791015625	0.000002384185791015625	0.000002384185791015625	1	2	3	4	5	6	7	8	9
0.000011920928955078125	0.0000011920928955078125	0.0000011920928955078125	1	2	3	4	5	6	7	8	9
0.0000059604644775390625	0.00000059604644775390625	0.00000059604644775390625	1	2	3	4	5	6	7	8	9
0.00000298023223876953125	0.000000298023223876953125	0.000000298023223876953125	1	2	3	4	5	6	7	8	9
0.000001490116119384765625	0.0000001490116119384765625	0.0000001490116119384765625	1	2	3	4	5	6	7	8	9
0.0000007450580596923828125	0.00000007450580596923828125	0.00000007450580596923828125	1	2	3	4	5	6	7	8	9
0.00000037252902984619140625	0.000000037252902984619140625	0.000000037252902984619140625	1	2	3	4	5	6	7	8	9
0.000000186264514923095703125	0.0000000186264514923095703125	0.0000000186264514923095703125	1	2	3	4	5	6	7	8	9
0.0000000931322574615478515625	0.00000000931322574615478515625	0.00000000931322574615478515625	1	2	3	4	5	6	7	8	9
0.00000004656612873077392578125	0.000000004656612873077392578125	0.000000004656612873077392578125	1	2	3	4	5	6	7	8	9
0.000000023283064365386962890625	0.0000000023283064365386962890625	0.0000000023283064365386962890625	1	2	3	4	5	6	7	8	9
0.0000000116415321826934814453125	0.00000000116415321826934814453125	0.00000000116415321826934814453125	1	2	3	4	5	6	7	8	9
0.00000000582076609133474072265625	0.00000000582076609133474072265625	0.00000000582076609133474072265625	1	2	3	4	5	6	7	8	9
0.0000000029103830456673703613125	0.0000000029103830456673703613125	0.0000000029103830456673703613125	1	2	3	4	5	6	7	8	9
0.00000000145519152283368518065625	0.00000000145519152283368518065625	0.00000000145519152283368518065625	1	2	3	4	5	6	7	8	9
0.0000000007275957614168425903125	0.0000000007275957614168425903125	0.0000000007275957614168425903125	1	2	3	4	5	6	7	8	9
0.00000000036379788070842129515625	0.00000000036379788070842129515625	0.00000000036379788070842129515625	1	2	3	4	5	6	7	8	9
0.000000000181898940354210647578125	0.000000000181898940354210647578125	0.000000000181898940354210647578125	1	2	3	4	5	6	7	8	9
0.0000000000909494701772053237890625	0.0000000000909494701772053237890625	0.0000000000909494701772053237890625	1	2	3	4	5	6	7	8	9
0.00000000004547473508860266189453125	0.00000000004547473508860266189453125	0.00000000004547473508860266189453125	1	2	3	4	5	6	7	8	9
0.0000000000227373675443013309473125	0.0000000000227373675443013309473125	0.0000000000227373675443013309473125	1	2	3	4	5	6	7	8	9
0.00000000001136868377215066547665625	0.00000000001136868377215066547665625	0.00000000001136868377215066547665625	1	2	3	4	5	6	7	8	9
0.0000000000056843418860753327383125	0.0000000000056843418860753327383125	0.0000000000056843418860753327383125	1	2	3	4	5	6	7	8	9
0.00000000000284217094303766636915625	0.00000000000284217094303766636915625	0.00000000000284217094303766636915625	1	2	3	4	5	6	7	8	9
0.000000000001421085471518833184578125	0.000000000001421085471518833184578125	0.000000000001421085471518833184578125	1	2	3	4	5	6	7	8	9
0.0000000000007105427357594165922953125	0.0000000000007105427357594165922953125	0.0000000000007105427357594165922953125	1	2	3	4	5	6	7	8	9
0.0000000000003552713678797082961473125	0.0000000000003552713678797082961473125	0.0000000000003552713678797082961473125	1	2	3	4	5	6	7	8	9
0.0000000000001776356839398541480738125	0.0000000000001776356839398541480738125	0.0000000000001776356839398541480738125	1	2	3	4	5	6	7	8	9
0.000000000000088817841969927074036953125	0.000000000000088817841969927074036953125	0.000000000000088817841969927074036953125	1	2	3	4	5	6	7	8	9
0.0000000000000444089209849635370184765625	0.0000000000000444089209849635370184765625	0.0000000000000444089209849635370184765625	1	2	3	4	5	6	7	8	9
0.000000000000022204460492481768505238125	0.000000000000022204460492481768505238125	0.000000000000022204460492481768505238125	1	2	3	4	5	6	7	8	9
0.00000000000001110223024624088425261953125	0.00000000000001110223024624088425261953125	0.00000000000001110223024624088425261953125	1	2	3	4	5	6	7	8	9
0.000000000000005551115123120442126309765625	0.000000000000005551115123120442126309765625	0.000000000000005551115123120442126309765625	1	2	3	4	5	6	7	8	9
0.000000000000002775557561560222063154878125	0.000000000000002775557561560222063154878125	0.000000000000002775557561560222063154878125	1	2	3	4	5	6	7	8	9
0.000000000000001387778780780111031577438125	0.000000000000001387778780780111031577438125	0.000000000000001387778780780111031577438125	1	2	3	4	5	6	7	8	9
0.000000000000000693889390390055515788721875	0.000000000000000693889390390055515788721875	0.000000000000000693889390390055515788721875	1	2	3	4	5	6	7	8	9
0.0000000000000003469446951950277578943608125	0.0000000000000003469446951950277578943608125	0.0000000000000003469446951950277578943608125	1	2	3	4	5	6	7	8	9
0.0000000000000001734723475975138789471804375	0.0000000000000001734723475975138789471804375	0.0000000000000001734723475975138789471804375	1	2	3	4	5	6	7	8	9
0.00000000000000008673617379875693947059021875	0.00000000000000008673617379875693947059021875	0.00000000000000008673617379875693947059021875	1	2	3	4	5	6	7	8	9
0.000000000000000043368086899378469725295109375	0.000000000000000043368086899378469725295109375	0.000000000000000043368086899378469725295109375	1	2	3	4	5	6	7	8	9
0.0000000000000000216840434496892349626475546875	0.0000000000000000216840434496892349626475546875	0.0000000000000000216840434496892349626475546875	1	2	3	4	5				



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 449 450 451 452 453 454 455 456 457 458 459 459 460 461 462 463 464 465 466 467 468 469 469 470 471 472 473 474 475 476 477 478 479 479 480 481 482 483 484 485 486 487 488 489 489 490 491 492 493 494 495 496 497 498 499 499 500 501 502 503 504 505 506 507 508 509 509 510 511 512 513 514 515 516 517 518 519 519 520 521 522 523 524 525 526 527 528 529 529 530 531 532 533 534 535 536 537 538 539 539 540 541 542 543 544 545 546 547 548 549 549 550 551 552 553 554 555 556 557 558 559 559 560 561 562 563 564 565 566 567 568 569 569 570 571 572 573 574 575 576 577 578 579 579 580 581 582 583 584 585 586 587 588 589 589 590 591 592 593 594 595 596 597 598 599 599 600 601 602 603 604 605 606 607 608 609 609 610 611 612 613 614 615 616 617 618 619 619 620 621 622 623 624 625 626 627 628 629 629 630 631 632 633 634 635 636 637 638 639 639 640 641 642 643 644 645 646 647 648 649 649 650 651 652 653 654 655 656 657 658 659 659 660 661 662 663 664 665 666 667 668 669 669 670 671 672 673 674 675 676 677 678 679 679 680 681 682 683 684 685 686 687 688 689 689 690 691 692 693 694 695 696 697 698 699 699 700 701 702 703 704 705 706 707 708 709 709 710 711 712 713 714 715 716 717 718 719 719 720 721 722 723 724 725 726 727 728 729 729 730 731 732 733 734 735 736 737 738 739 739 740 741 742 743 744 745 746 747 748 749 749 750 751 752 753 754 755 756 757 758 759 759 760 761 762 763 764 765 766 767 768 769 769 770 771 772 773 774 775 776 777 778 779 779 780 781 782 783 784 785 786 787 788 789 789 790 791 792 793 794 795 796 797 798 799 799 800 801 802 803 804 805 806 807 808 809 809 810 811 812 813 814 815 816 817 818 819 819 820 821 822 823 824 825 826 827 828 829 829 830 831 832 833 834 835 836 837 838 839 839 840 841 842 843 844 845 846 847 848 849 849 850 851 852 853 854 855 856 857 858 859 859 860 861 862 863 864 865 866 867 868 869 869 870 871 872 873 874 875 876 877 878 879 879 880 881 882 883 884 885 886 887 888 889 889 890 891 892 893 894 895 896 897 898 899 899 900 901 902 903 904 905 906 907 908 909 909 910 911 912 913 914 915 916 917 918 919 919 920 921 922 923 924 925 926 927 928 929 929 930 931 932 933 934 935 936 937 938 939 939 940 941 942 943 944 945 946 947 948 949 949 950 951 952 953 954 955 956 957 958 959 959 960 961 962 963 964 965 966 967 968 969 969 970 971 972 973 974 975 976 977 978 979 979 980 981 982 983 984 985 986 987 988 989 989 990 991 992 993 994 995 996 997 998 999 999 1000

בְּנֵי יִשְׂרָאֵל

בְּנֵי יִשְׂרָאֵל

הַבְּנָה כִּי-זֶה אֵין כִּי-זֶה

בְּנֵי יִשְׂרָאֵל

וְיַעֲשֵׂה יְהוָה כָּל־אֲשֶׁר־יֹאמְרָה לְךָ

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<p>INTER ELEMENT CONNECTIONS FOR ELEMENT NO. 0</p> <p>Element No. 0 consists of a vertical column of 12 nodes. Node 1 is at the top and node 12 is at the bottom. The connections are as follows:</p> <ul style="list-style-type: none"> <li>Node 1 is connected to node 2.</li> <li>Node 2 is connected to node 3.</li> <li>Node 3 is connected to node 4.</li> <li>Node 4 is connected to node 5.</li> <li>Node 5 is connected to node 6.</li> <li>Node 6 is connected to node 7.</li> <li>Node 7 is connected to node 8.</li> <li>Node 8 is connected to node 9.</li> <li>Node 9 is connected to node 10.</li> <li>Node 10 is connected to node 11.</li> <li>Node 11 is connected to node 12.</li> </ul>	<p>ELEMENT NO. 0.</p>
<p>INTER ELEMENT CONNECTIONS FOR ELEMENT NO. 1</p> <p>Element No. 1 consists of a vertical column of 12 nodes. Node 1 is at the top and node 12 is at the bottom. The connections are as follows:</p> <ul style="list-style-type: none"> <li>Node 1 is connected to node 2.</li> <li>Node 2 is connected to node 3.</li> <li>Node 3 is connected to node 4.</li> <li>Node 4 is connected to node 5.</li> <li>Node 5 is connected to node 6.</li> <li>Node 6 is connected to node 7.</li> <li>Node 7 is connected to node 8.</li> <li>Node 8 is connected to node 9.</li> <li>Node 9 is connected to node 10.</li> <li>Node 10 is connected to node 11.</li> <li>Node 11 is connected to node 12.</li> </ul>	<p>ELEMENT NO. 1.</p>
<p>INTER ELEMENT CONNECTIONS FOR ELEMENT NO. 2</p> <p>Element No. 2 consists of a vertical column of 12 nodes. Node 1 is at the top and node 12 is at the bottom. The connections are as follows:</p> <ul style="list-style-type: none"> <li>Node 1 is connected to node 2.</li> <li>Node 2 is connected to node 3.</li> <li>Node 3 is connected to node 4.</li> <li>Node 4 is connected to node 5.</li> <li>Node 5 is connected to node 6.</li> <li>Node 6 is connected to node 7.</li> <li>Node 7 is connected to node 8.</li> <li>Node 8 is connected to node 9.</li> <li>Node 9 is connected to node 10.</li> <li>Node 10 is connected to node 11.</li> <li>Node 11 is connected to node 12.</li> </ul>	<p>ELEMENT NO. 2.</p>
<p>INTER ELEMENT CONNECTIONS FOR ELEMENT NO. 3</p> <p>Element No. 3 consists of a vertical column of 12 nodes. Node 1 is at the top and node 12 is at the bottom. The connections are as follows:</p> <ul style="list-style-type: none"> <li>Node 1 is connected to node 2.</li> <li>Node 2 is connected to node 3.</li> <li>Node 3 is connected to node 4.</li> <li>Node 4 is connected to node 5.</li> <li>Node 5 is connected to node 6.</li> <li>Node 6 is connected to node 7.</li> <li>Node 7 is connected to node 8.</li> <li>Node 8 is connected to node 9.</li> <li>Node 9 is connected to node 10.</li> <li>Node 10 is connected to node 11.</li> <li>Node 11 is connected to node 12.</li> </ul>	<p>ELEMENT NO. 3.</p>







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**APPENDIX C**

## APPENDIX C

### DYNTACS FAMILY REFERENCE DOCUMENTS

#### THE TANK WEAPON SYSTEM

<u>Date</u>	<u>Subject</u>	<u>DDC-AD#</u>
1963 Annual Report	The Tank Weapon System (Howland and Bonder)	409899
1963 Classified Annex		338373
1963 Progress Report	The Tank Weapon System	427793
1964 Tech. Report	Vibrations of a Multi-Wheeled Vehicle (Bussman)	604693
1964 Annual Report	The Tank Weapon System	447494
1965 Annual Report (U)	The Tank Weapon System	471302
1965 Annual Report (S)		366070
1965 Tech. Report	A Generalized Lanchester Model to Predict Weapon Performance in Dynamic Combat (Bonder)	471300
1965 Tech. Report	Tank Mobility in Soft Soils (Perloff)	471301
1966 Annual Report (U)1	The Tank Weapon System (Howland and Clark)	801900
1966 Annual Report (U)2	The Tank Weapon System (Howland and Clark)	8150
1966 Classified Annex C	The Tank Weapon System	378607

<u>e</u>	<u>Subject</u>	<u>DDC-AD#</u>
8 Annual Report (U) 1 Sept. 1968	The Tank Weapon System	850367
9 Annual Report Oct. 1969	The Tank Weapon System (Bishop and Clark)	864919
9 Annual Report Sept. 1969	The Tank Weapon System (Bishop and Clark)	864920
9 Annual Report June 1969	The Tank Weapon System (Clark and Moss)	864921
9 Annual Report June 1969	The Tank Weapon System (Clark and Moss)	864922
9 Annual Report Sept. 1969	The Tank Weapon System (Bishop and Clark)	864923

#### THE LAND COMBAT MODEL

<u>l.</u>	<u>Subject</u>	<u>DDC-AD#</u>
	The Land Combat Model (DYNCOM) (Bishop and Clark)	909540
	To be published	
	The Aerial Platform Operations Module May 1971 (Clark and Hutch- er- son)	887264
1	DYNCOM Programmer's Man- ual (Clark, Parry, Hutch- erson, Rheinfrank, and Petty)	872508
3	DYNCOM Programmer's Man- ual (Clark, Parry, Hutch- erson, Rheinfrank, and Petty)	872508
	Classified Annex, edited by Clark, Parry, Rhein- frank (SECRET)	517621

## SMALL UNIT COMBAT SIMULATION (DYNATACS X)

	<u>Subject</u>	<u>DDC-AD#</u>
	Counterbattery Fire Models (Clark and Parry)	882877
	Air Defense Operations Models (Clark, Parry, Hutcherson and Rhein- frank)	887265-L
	Air Defense Operations Models (Clark, Parry, Hutcherson and Rhein- frank)	887266-L
	Fire Support Operations Models (Clark and Hutcherson)	890443
(Section I)	Fire Support Operations Models (Clark and Hutcherson)	889577
(Section II)	Fire Support Operations Models (Clark and Hutcherson)	889628

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